96th Congress
1st Session

COMMITTEE PRINT

Committee
Print 96-IFC 20

FEDERAL GOVERNMENT INCENTIVES TO COAL AND NUCLEAR ENERGY

A STUDY

PREPARED AT THE REQUEST OF THE

SUBCOMMITTEE ON ENERGY AND POWER

COMMITTEE ON
INTERSTATE AND FOREIGN COMMERCE
UNITED STATES
HOUSE OF REPRESENTATIVES

BY THE

CONGRESSIONAL RESEARCH SERVICE
LIBRARY OF CONGRESS

MAY 1979

Printed for the use of the Committee on Interstate and Foreign Commerce, United States House of Representatives

---

U.S. GOVERNMENT PRINTING OFFICE
46-139
WASHINGTON : 1979

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

COMMITTEE ON INTERSTATE AND FOREIGN COMMERCE

HARLEY O. STAGGERS, West Virginia, *Chairman*

JOHN D. DINGELL, Michigan
LIONEL VAN DEERLIN, California
JOHN M. MURPHY, New York
DAVID E. SATTERFIELD III, Virginia
BOB ECKHARDT, Texas
RICHARDSON PREYER, North Carolina
JAMES H. SCHEUER, New York
RICHARD L. OTTINGER, New York
HENRY A. WAXMAN, California
TIMOTHY E. WIRTH, Colorado
PHILIP R. SHARP, Indiana
JAMES J. FLORIO, New Jersey
ANTHONY TOBY MOFFETT, Connecticut
JIM SANTINI, Nevada
ANDREW MAGUIRE, New Jersey
MARTY RUSSO, Illinois
EDWARD J. MARKEY, Massachusetts
THOMAS A. LUKEN, Ohio
DOUG WALGREN, Pennsylvania
ALBERT GORE, Jr., Tennessee
BARBARA A. MIKULSKI, Maryland
RONALD M. MOTTL, Ohio
PHIL GRAMM, Texas
AL SWIFT, Washington
MICKEY LELAND, Texas
RICHARD C. SHELBY, Alabama

SAMUEL L. DEVINE, Ohio
JAMES T. BROYHILL, North Carolina
TIM LEE CARTER, Kentucky
CLARENCE J. BROWN, Ohio
JAMES M. COLLINS, Texas
NORMAN F. LENT, New York
EDWARD R. MADIGAN, Illinois
CARLOS J. MOORHEAD, California
MATTHEW J. RINALDO, New Jersey
DAVE STOCKMAN, Michigan
MARC L. MARKS, Pennsylvania
TOM CORCORAN, Illinois
GARY A. LEE, New York
TOM LOEFFLER, Texas
WILLIAM E. DANNEMEYER, California

W. E. Williamson, *Chief Clerk and Staff Director*
Kenneth J. Painter, *First Assistant Clerk*
Wm. Michael Kitzmiller, *Professional Staff*
Randall E. Davis, *Associate Minority Counsel*

Subcommittee on Energy and Power

JOHN D. DINGELL, Michigan, *Chairman*

RICHARD L. OTTINGER, New York
PHILIP R. SHARP, Indiana
ANTHONY TOBY MOFFETT, Connecticut
DAVID E. SATTERFIELD III, Virginia
TIMOTHY E. WIRTH, Colorado
EDWARD J. MARKEY, Massachusetts
PHIL GRAMM, Texas
AL SWIFT, Washington
RICHARD C. SHELBY, Alabama
ANDREW MAGUIRE, New Jersey
ALBERT GORE, Jr., Tennessee
MICKEY LELAND, Texas
HARLEY O. STAGGERS, West Virginia
(Ex Officio)

CLARENCE J. BROWN, Ohio
CARLOS J. MOORHEAD, California
JAMES M. COLLINS, Texas
DAVE STOCKMAN, Michigan
TOM CORCORAN, Illinois
TOM LOEFFLER, Texas
SAMUEL L. DEVINE, Ohio
(Ex Officio)

Frank M. Potter, Jr., *Staff Director and Counsel*

LETTER OF TRANSMITTAL

CONGRESS OF THE UNITED STATES,
HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON ENERGY AND POWER,
COMMITTEE ON INTERSTATE AND FOREIGN COMMERCE,
Washington, D.C., May 29, 1979.

Hon. HARLEY O. STAGGERS,
Chairman, Committee on Interstate and Foreign Commerce,
U.S. House of Representatives, Washington, D.C.

DEAR MR. CHAIRMAN: Attached is a study performed by the Congressional Research Service for the Subcommittee on Energy and Power entitled: "A Study of Federal Government Incentives to Coal and Nuclear Energy". I believe it would be useful if this study were to be published as a committee print.

The study, coordinated by Mr. Russell J. Profozich, Analyst in Energy and Utilities, Economics Division, details the various federally provided incentives to the coal and nuclear industry. The study also summarizes the findings of the two other reports on the subject.

I believe that all Members of the House will find the study to be of interest.

Sincerely,

JOHN D. DINGELL, *Chairman.*

Enclosure.

LETTER OF SUBMITTAL

THE LIBRARY OF CONGRESS,
CONGRESSIONAL RESEARCH SERVICE,
WASHINGTON, D.C., *March 2, 1979.*

Hon. JOHN DINGELL,
Chairman, Subcommittee on Energy and Power,
Committee on Interstate and Foreign Commerce,
U.S. House of Representatives,
Washington, D.C.

DEAR MR. CHAIRMAN: In response to your request, I am submitting a report on Federal Government incentives to coal and nuclear energy.

The report is an analysis of those Federal Government programs which provide incentives to production of coal and nuclear energy. Also included in the report are summaries of several previous studies of this topic.

The report was coordinated, and sections I through IV were written by Russell J. Profozich, Analyst in Energy and Utilities, Economics Division. Sections V and VI were prepared by Migdon Segal, Analyst in Science and Technology, Science Policy Research Division. Section VII was written by Joseph P. Biniek, Specialist in Environment and Natural Resources, Environment and Natural Resources Policy Division; sections VIII and IX were written by Alvin Kaufman, Senior Specialist, Mineral and Regulatory Economics and Susan J. Bodilly, Research Assistant, Office of Senior Specialists; section X was prepared by Donald W. Kiefer, Specialist in Taxation and Fiscal Policy, Economics Division.

We trust that this report will serve the needs of your Subcommittee as well as those of other committees and Members of Congress concerned with energy matters.

Sincerely,

GILBERT GUDE, *Director.*

Enclosures.

Abstract

The purpose of this report is to identify and quantify as much as possible Federal Government programs which provide incentives to the coal and nuclear energy industries. The costs of these programs are borne by the public sector of the U.S. economy and thus they may act to distort the market prices of competitive energy sources, although it may be presumed that these programs provide benefits to society, as well as impose costs upon it.

CONTENTS

46–139—79——2

Federal Government Incentives to Coal and Nuclear Energy *

INTRODUCTION

The Federal Government has been involved in programs which act as a stimulus to energy production for a large number of years. For instance, the Mining Law of 1872 was established to administer Public Lands on which mineral deposits are located. The involvement of the Federal Government in energy production has taken on many forms and includes such programs as land leasing laws, depletion allowances, accelerated depreciation and investment tax credits, purchasing programs, minimum price controls, data collection activities, research and development activities, Government enrichment services and Government regulatory activities. Also, indirect benefits to the energy industries have been provided through such Government programs as Federal expenditures for ports and waterways and Federal subsidies to railroads. These methods of transportation are used to transport much of the Nation's coal and other energy supplies.

Federally supplied benefits to the coal and nuclear energy industries can be seen as an interference in the competitive market forces which determine the prices charged for these (and other) energy sources (although it must be remembered that many of these actions are undertaken in order to correct perceived imperfections in the market). This is not to say that these Federal incentives are good or bad, for a Government-supplied benefit or subsidy to a particular energy industry may indeed supply a benefit to society which the free market system would not have supplied and the benefits of which outweigh the costs. However, Government furnished incentives to industry may also be wasteful if the perceived benefits derived therefrom are illusory or if the costs of the program are greater than its benefits.

The purpose of the immediate study is not to discuss the relative merits of Federal Government incentives to the coal and nuclear energy industries, but simply to present in as comprehensive a manner as possible the amounts of federally provided incentives to these two energy industries. It can be stated, however, that the benefits provided to these two competitive energy sources interfere with the decisions of consumers when they choose between these (and other) energy supplies. This is so because the benefits provided to the energy industries often are not reflected in the final price of the energy product. For example, Government-provided benefits to the rail and water transportation industries in the form of land grants and expenditures on ports and waterways also provide benefits to the energy industries in the form of lower transportation costs. Coal, 76 percent of which

* A study prepared by Russell J. Profozich, analyst in energy and utilities; Alvin Kaufman, senior specialist, mineral and regulatory economics; Donald W. Kiefer, specialist in taxation and fiscal policy; Migdon Segal, analyst in science and technology; Joseph P. Biniek, specialist in environment and natural resources; and Susan J. Bodilly, research assistant, office of Senior Specialists, of the Library of Congress, Congressional Research Service.

was shipped by rail or water transportation in 1975, receives an indirect benefit, then, from the Government programs aiding the transportation industry. If the benefit provided to the nuclear industry (either directly or indirectly) through Government programs is disproportionate to that provided to the coal industry (or other energy industries) then the relative market prices of these competing energy sources will in varying degrees be unreflective of the true costs of production. A portion of the production costs will be borne by the public sector of the economy rather than by the private sector. Consumers will then be basing their consumption decisions on prices which do not fully reflect the costs of production.

This situation gains increased importance when one considers the introduction into the market place of a new competitive energy source such as solar energy. If solar energy must compete in the market place on its own merits, that is, without Government provided subsidies or benefits, then it will likely be at a disadvantage in comparison with other forms of energy which have been receiving Government incentives for quite some time. Also, in order to determine what, if any, incentives should be provided to the solar energy industry, an analysis of the types of incentives already provided to the other energy sources might be helpful. A study for the Department of Energy (DOE) which is summarized in the next section of this report, analyzed the Federal incentives to energy production for purposes of determining which incentives could be applied to the solar energy industry. As reported in *Not Man Apart*, a publication of Friends of the Earth, the amount of federally supplied incentives to the energy industries from 1920 through 1976, in 1976 dollars, according to the DOE study, totaled \$0.09 per million BTU of energy supplied by the oil industry from 1920 through 1976; \$0.03 per million BTU supplied by the gas industry (1920–1976); \$0.12 to \$0.23 per million BTU for the hydroelectric industry (1930–1976); \$0.015 per million BTU supplied by the coal industry (1940–1976); and \$6.51 to \$7.27 per million BTU supplied by the nuclear energy industry for the period 1950 through 1976.[1] Thus, according to the DOE report, nuclear energy has received by far the greatest amount of Federal Government incentives on a BTU delivered basis than have the other major energy sources.

It should be noted at this time, however, that the Federal Government imposes costs upon energy producers as well as providing benefits. The DOE report summarized in the Friends of the Earth publication considered only the Federal incentives to energy production, it did not consider any Government imposed costs upon the industries. It is also not the purpose of this study to make estimates of Federal Government imposed costs or disincentives to energy production which may act to offset the benefits provided through Government programs. But certainly such actions as Federal Government environmental, health and safety requirements and regulations and price controls impose some costs upon energy producers. These costs, however, would certainly prove to be as difficult to measure as the benefits provided by the Government which are estimated and summarized in the remainder of this report. For instance, one of the

[1] Not Man Apart, Friends of the Earth, Mid October–November 1978, Vol. 8, No. 14, p. 11.

following sections reports that in 1977 the Federal Government spent $1.16 billion on civilian nuclear energy research and development (R & D). This funding is obviously a Government provided benefit to the industry which has expanded over the last 30 years largely as a result of Government development of nuclear energy. But how much of this expenditure was a benefit to the industry? Were these dollars well spent or could private industry have sponsored R & D activities at a lower cost? And what benefits were provided to society as a result of this governmental activity? The development of nuclear energy certainly allows us to conserve our dwindling supplies of fossil fuels and also reduces our dependence on imports of foreign energy. But what about the environmental and health effects associated with nuclear power?

The purpose of this report is not to analyze the many issues related to Federal Government involvement in the energy industries. These issues are mentioned here only to point out that one must be careful in interpreting data which is intended to show the level of governmental incentives or subsidies to a particular industry or segment within an industry. First of all, much interpretation of data and information is necessary to derive the figures which are presented in the tables which follow in this report. Also, because of the large number of governmental agencies and programs involved, it is extremely difficult to derive figures which encompass all of the benefits provided to the various energy industries. Therefore, while the studies which are summarized in this report and the information presented in the tables and appendices are intended to display the major Federal Government incentives to the coal and nuclear energy industries, the data is not all-encompassing.

The following section of this report presents summaries of portions of two recent studies which analyzed Federal Government incentives to energy production. The succeeding sections contain estimates of various Government incentives to the coal and nuclear industries as derived by Congressional Research Service analysts. Appendix III contains copies of several previous CRS products which deal with the subject at hand.

I. RECENT STUDIES ON GOVERNMENT INCENTIVES TO ENERGY [2]

1. *Summary of Battelle Report* [3]

The purpose of the Battelle report was to identify and quantify current and historic Federal Government incentives that have been utilized to stimulate energy production. This analysis is then related to the solar energy industry in an effort to differentiate those Federal incentives which might be used to stimulate the development and commercialization of solar energy throughout the U.S. The report states that the U.S. Government has historically created incentives designed to stimulate production of specific energy sources. These incentives have resulted in imperfectly competitive energy markets since a part of the cost of production is borne by the public sector of

---

[2] Sections I, II, III and IV prepared by Russell Profozich, Economics Divisions.

[3] An Analysis of Federal Incentives Used to Stimulate Energy Production, Prepared for the U.S. Department of Energy by Battelle Pacific Northwest Laboratories, March 1978.

the economy and thus is not reflected in the price of the various energy sources.

The report defines a Federal incentive as any action that can be taken by the Government to expand residential and commercial use of energy. Economic, political, organizational and legal viewpoints were considered in formulating the analysis and eight types of Federal incentives were identified: [4]

(1) Creation or prohibition of existing taxes.

(2) Taxation exemption, or reduction of existing taxes.

(3) Collection of fees for delivery of a governmental service or good not directly related to the cost of providing that good or service.

(4) Disbursements in which the Federal Government distributes money without requiring anything in return.

(5) Requirements made by the Government backed by criminal or civil sanctions.

(6) Traditional Government services through a nongovernmental entity without direct charge (i.e., regulating interstate and foreign commerce and providing inland waterways).

(7) Nontraditional Government services such as exploration, research, development and demonstration of new technology.

(8) Market activity under conditions similar to those faced by nongovernmental producers or consumers.

Federal Government incentives to energy production were identified and quantified for the hydro, nuclear, coal, gas and oil industries. Total Federal Government expenditures for incentives to stimulate energy production for these industries for the peroid 1918 through 1976, in constant 1976 dollars, was estimated to be between $123.6 billion and $133.7 billion.[5] Of this total, it was estimated that the coal industry received 5 percent of the total Federal Government expenditures, or $6.8 billion, and the nuclear industry $15.3 billion to $17.1 billion or 13 percent of total expenditures.

(*a*) *Incentives to the nuclear industry*

The Federal Government incentives to nuclear energy include $14.2 billion for research and development (R & D) activities. The Battelle report derived these figures from an analysis of funds spent on development of commercial nuclear power performed by the Controller's Office of the Energy Research and Development Administration (ERDA) covering the period from fiscal year (FY) 1950 through FY 1977. Government funding for development of commercial nuclear power includes contributions made to the following programs:

Nuclear materials;
Lasar fusion;
Controlled thermonuclear reaction;
Civilian reactor development;
Advanced isotope separations;
Waste management;
Reactor safety research;
Other applied energy;
Resource assessment; and
Reactor safety facilities.

---

[4] Ibid., p. 1.
[5] Battelle Pacific Northwest Laboratories, op. cit., p. 262 and Table 51, p. 263.

Using the ERDA data, the Battelle report estimated that Federal funding for these programs in relation to commercial nuclear energy totaled $12.4 billion in 1976 dollars. However, this figure does not include R & D expenditures for other supporting technology in the areas of biology, environmental science, education information, training, and program management costs. By making several simplifying assumptions involving the relative joint costs and benefits of the military and space nuclear programs and the commercial nuclear energy program, Battelle determined that an additional $1.8 billion in Federal Government expenditures should properly be allocated to commercial nuclear energy R & D activities, bringing the total to $14.2 billion 1976 dollars.

The Battelle estimate of Federal Government incentives to nuclear power also includes $1.7 billion (in 1976 dollars) for Government supplied enrichment services. Since Government enrichment facilities were originally built to supply enrichment services for military purposes, and since they also supply enrichment services to foreign customers, many problems are encountered in allocating a portion of the costs involved in building and operating these facilities to the commercial nuclear industry. The figure derived by Battelle includes $0.5 billion which is the estimated difference in the price of enrichment services provided by the Government through 1974 and the price which would have been charged for these services had they been supplied by a private company and included charges for insurance, Federal, State and local taxes, and a factor to cover economic risks. To this figure, Battelle adds $1.2 billion which is the unrecovered cost of expanding Government enrichment facilities for commercial purposes.

The final cost figure for Government-provided incentives to nuclear energy, as presented by Battelle, is $1.2 billion in 1976 dollars for the cost of Federal regulation (by the Nuclear Regulatory Commission and its predecessor, the Atomic Energy Commission) of the nuclear industry from FY 1960 through FY 1977. Before 1960, Battelle states, most regulatory activities were for defense purposes and thus their cost was not included in the analysis.

The Battelle report did consider other Federal Government provided incentives to the nuclear energy industry, but concluded that these incentives were unquantifiable. These unquantifiable incentives include the value to the industry of the liability insurance provided by the Price-Anderson Act and various incentives provided to the uranium mining industry including Atomic Energy Commission procurement policies; and tax policies.

(*b*) *Incentives to the coal industry*

The $6.8 billion in 1976 dollars of federally provided incentives to the coal industry, as reported in the Battelle report, include $1.66 billion of Federal funds spent in coal R & D programs from 1960 through 1975. This figure includes expenditures by the Environmental Protection Agency, the Bureau of Mines, the Office of Coal Research, and ERDA. Also, included in the total figure for Federal incentives to the coal industry is $72.6 million for federally supported exploration and examination of coal inventories undertaken by the U.S. Geological Survey from 1964 through 1976; $9 million attributable to coal leasing costs incurred by the Bureau of Land Management during the same time period; $3.0 billion revenue equivalent of the percentage

depletion allowance for coal mining for the period 1954 through 1976; $43 million for the cost of data collection and analysis of coal production and price data on behalf of the Bureau of Mines for the 1964 through 1976 period; $413 million for expenditures on mine health and the Mining Enforcement and Safety Administration from 1964 through 1976; and $1.76 billion for Federal expenditures for ports and waterways used in the transportation of coal from 1954 through 1975.

In addition to the above mentioned Federal Government incentives to the coal industry, several other governmental programs were mentioned in the Battelle report. However, no monetary value was placed on these activities, thus they were not included in the total dollar value figure for governmental incentives to the industry. These activities include various tax rules applicable to coal exploration expenditures; minimum price controls occasioned under the National Recovery Act and Bituminous Coal Act of 1935 and 1937; incentives for the development of small mines under the Energy Conservation and Oil Policy Act of 1975; Federal subsidies to railroads, which in 1975 carried 65 percent of total coal shipments; and the Energy Supply and Environmental Coordination Act and Energy Policy and Conservation Act which required electric utilities and other major fuel burning installations to convert from alternative sources of energy to domestic coal.

2. Summary of House Report No. 95–1080[6]

A study of nuclear power costs performed by the House Subcommittee on Environment, Energy, and Natural Resources of the Committee on Government Operations analyzed the economic costs to energy producers, consumers, and taxpayers of electrical energy produced from nuclear fuel. Included in this report is a discussion on "hidden subsidies" to nuclear power plants. One of the issues mentioned as a subsidy provided to utilities in relation to construction of nuclear generating facilities is the inclusion of construction work in progress (CWIP) in the utility rate base. During hearings on nuclear power costs, the report notes that Federal Power Commission (FPC) Vice Chairman Don Smith stated that in jurisdictions where CWIP is allowed in the rate base, current ratepayers pay more over a longer period of time for electricity produced by nuclear generation than by other, non-nuclear plants. This is so because of the higher investment costs and longer lead times necessary to build nuclear facilities as opposed to non-nuclear facilities.[7]

Another incentive provided to utilities in constructing nuclear generating facilities, according to the subcommittee report, is the reduction in Federal income taxes resulting from application of investment tax credits and accelerated depreciation allowance. Federal tax laws provide private utility companies with substantial tax benefits when they invest in new equipment. A study performed by the Environmental Action Foundation, the report notes, found that in 1975

[6] Nuclear Power Costs, Twenty-Third Report by the Committee On Government Operations, together with Additional, Minority, And Dissenting Views, 95th Congress, 2nd Session, House Report No. 95–1090, U.S. Govt. Printing Office, Washington, D.C., 1978, 148 p.

[7] Prepared Statement of Don S. Smith, Vice Chairman, Federal Power Commission, Nuclear Power Costs (Part 1), Hearings before a Subcommittee on Governmental Operations, House of Representatives, 95th Congress, 1st Session, September 12, 13, 14 and 19, 1977, U.S. Govt. Printing Office, Washington, D.D., 974 p.

the disparity between taxes charged to customers and taxes actually paid to the Government by the major power companies was approximately $1.5 billion. Again relying on the testimony of the FPC's Don Smith, the report states the higher capital cost of nuclear plants means larger dollar amounts of depreciation, lower present tax liability, and larger deferred taxes than would be the case if a lower capital cost fossil fueled plant were built. In addition, nuclear plants are allowed a shorter depreciation period for tax purposes than are fossil fueled plants. (Nuclear plants can be depreciated over a 16-year lifespan as compared to 22½ years for conventional power plants.)

A final "subsidy" to nuclear power mentioned in the report is that provided by Government enrichment of uranium for use in nuclear generating facilities. The report quotes Energy Secretary James Schlesinger in stating that ". . . existing prices of enrichment reflect construction costs of plants built in the 1940's and 1950's, almost 50 percent of which have been depreciated against government defense requirements, but which are now used principally for civilian purposes. The result is a substantial subsidy for nuclear plants."

II. TRANSPORTATION OF RADIOACTIVE MATERIALS

The transportation of radioactive materials is regulated at the Federal level by the Nuclear Regulatory Commission (NRC) and the Department of Transportation (DOT). The NRC's authority to regulate the packaging, shipment and carriage of nuclear materials is provided by the Atomic Energy Act of 1954, as amended. The primary purpose of the regulations regarding the transportation of nuclear materials on behalf of the NRC is to protect the health and safety of the public. The NRC is also responsible to provide for the common defense and security of the Nation in regard to nuclear materials and thus has established other regulations involving the transportation of radioactive materials which are designed to protect the public against diversion or use of the materials for unlawful purposes. Compliance with the NRC's regulations is verified by the Inspection and Enforcement Division which inspects communication systems, audits records kept by licensees and shippers and monitors shipments at various points of origin, destination and transfer.

The Department of Transportation has several statutory sources which provide authority to regulate the transportation of hazardous materials. The Transportation of Explosives Act provides authority for DOT to regulate shippers and highway and rail carriers of hazardous materials. The Federal Aviation Act of 1958 provides regulatory authority over the transportation of hazardous materials by air carriers, and the Dangerous Cargo Act provides for DOT authority over water borne shipments. Other statutory sources of authority include the Ports and Waterway Safety Act, the Hazardous Materials Transportation Act, and the Rail Safety Improvement Act of 1974.

The DOT has issued a special set of regulations that govern the transportation of radioactive materials, the authority over which is provided by DOT's responsibility to regulate the transportation of hazardous materials. These regulations cover the areas of packaging, international shipment, marking, placarding, shipping papers, and types of radioactive materials.

46-139—79——3

Within the DOT, the responsibility for regulation of the transportation of radioactive materials lies within the jurisdiction of the Materials Transportation Bureau, Office of Hazardous Materials. The fiscal year 1978 budget for the Office of Hazardous Materials was \$3.495 million and \$3.727 million was requested for fiscal year 1979.[8] Only a small part of the total budget would be applicable to the regulation of transportation of radioactive materials since the function is but one of the Bureau's responsibilities. No spearate budget figures by function are currently available.

NRC regulation of the transportation of radioactive materials is but one of the regulatory responsibilities of that agency, the cost of which will be taken up in the following section.

III. FEDERAL REGULATION OF THE NUCLEAR INDUSTRY

The Atomic Energy Commission (AEC) was established by Congress through enactment of the Atomic Energy Act of 1946. The AEC was given the responsibility to protect the health and safety of the public with regard to the use of nuclear energy and to regulate and control the use of nuclear materials. In 1975, the Energy Reorganization Act separated the regulatory functions of the AEC from the developemental functions and created the Nuclear Regulatory Commission (NRC). The NRC is charged with the responsibility of regulating the design, construction and operation of civilian nuclear power plants and associated facilities so that the public health and safety, the natural security and the quality of the environment are adequately protected, and the antitrust lasws are obeyed.

An analysis of Federal incentives to stimulate U.S. energy production performed by Battelle Pacific Northwest Laboratories for the Department of Energy reported AEC and NRC regulatory costs for the fiscal years 1960 through 1977. The report shows that a total of \$880.80 million was spent by the AEC and its successor agency the NRC on regulation of the commercial nuclear power industry during this period. This amount translates to a total expenditure of \$1.2 billion in 1976 dollars.[9] In addition to this amount, the NRC budgeted \$117.46 million in 1978, out of a total budget of \$294.59 million for the purposes of nuclear reactor regulation, standards development, inspection and enforcement, and nuclear material safety and safeguards.[10] The amount appropriated for these same functions for fiscal year 1979 totals \$128.02 million out of a total NRC budget of \$333.01 million.[11]

IV. RADIOACTIVE WASTE MANAGEMENT AND DISPOSAL

A major dilemma facing the nuclear energy industry is how to store the increasing amounts of radioactive wastes. Nuclear fission power plants produce approximately 10,000 gallons of high- and low-level wastes each year which remain hazardous to man and the environment

---

[8] Deparment of Transportation and Related Agencies Appropriations For 1979, Hearings before a Subcommittee on the Committee on Appropriations, U.S. House of Representatives, 95th Congress, 2nd Session, Part 2, U.S. Govt'. Print. Off., Washington, D.C., 1978, p. 737.

[9] An Analysis of Federal Incentives Used to Stimulate Energy Production, Prepared for the U.S. Department of Enegy by Battelle Pacific Laboratories, March 1978, p. 145.

[10] Nuclear Regulatory Commission Authorizations, Report of the Committee on Environment and Public Works, U.S. Senate, to accompany S. 2584, 95th Congress. 2nd Session, Report No. 95–848, U.S. Gov't. Print. Off., Washington, D.C., 1978, p. 7.

[11] Ibid.

for thousands of years. Low-level wastes do not have the long toxic lives of the wastes created in power plant operations, but because they are produced at every other stage throughout the nuclear fuel cycle they are accumulated in large quantities. Both liquid and solid low-level wastes are produced during uranium mining, milling, enrichment, and fuel fabrication activities.

No solution has yet been found for the safe and permanent storage of radioactive wastes. There is at the present time no comprehensive government program for the handling of radioactive wastes generated by commercial power plants. NRC regulations for commerically produced high-level wastes simply require the solidification of liquid wastes within five years after reprocessing and shipment within ten years to a Federal repository. In the meantime, radioactive wastes generated by nuclear power plants are being stored at the reactor site or shipped to government storage facilities.

With the current Federal Government position to indefinitely defer commerical reprocessing of spent fuel, the DOE and the NRC are continuing to fund development of methods for storage and disposal of commerical nuclear wastes. The DOE funding for this R & D (and the historical funding by the AEC and ERDA) are included in the figures presented in Table 1.

In addition to these federally funded research activities, the 95th Congress passed legislation (H.R. 13650 and S. 3078) and the President signed into law (Public Law 95–604) the Uranium Mill Tailing Control Act of 1978. This Act puts the primary financial burden on the Federal Government for removing and burying the tailings piles accumulated at more than 20 shut-down milling sites in various States throughout the Nation. This legislation provides for the Federal Government to pay for 90 percent of the cost of the appropriate remedial action necessary to be carried out at each processing site with the State in which the site is located to pay the remaining 10 percent. Also, the legislation provides authority to the NRC to regulate the environmental and health aspects of mill tailings both at operating and inactive milling sites.

V. COST OF FEDERAL FUNDING FOR CIVIL NUCLEAR R. & D. [12]

The following table lists budget figures for the civilian nuclear power development program for fiscal years from 1948 to the present. The year 1948 was chosen as the starting point, because the civilian nuclear research program did not really begin until that fiscal year, with the creation of the Atomic Energy Commission (AEC).

The table shows the relevant portion of the AEC budget for fiscal years 1948–1974. After that time, it shows the budget for the successor agencies to the AEC (first ERDA, then DOE). For fiscal years 1948–1969, the source of this data is "Federal Expenditures Relating to Civil Nuclear Power, Fiscal Years 1948–1974," by Dr. Warren H. Donnelly of CRS, June 22, 1973. For fiscal years 1970–1979, the source is "R & D Related to Civilian Reactor Development—Budget Outlays," prepared by DOE's Budget Office, March 7, 1978.

For fiscal years 1948–1954, the table includes all reactor development, since civil and military reactor development programs were not separated at that time. For fiscal years 1955–1969, the figures given

are for civilian power related reactor development. For fiscal years 1970–1979, the figures include other items in addition to reactor development, such as magnetic fusion, uranium enrichment process development, fuel cycle R & D (including waste management and disposal), and safety-related research. Since the funding for these programs was not large during the 1970–1972 period, the omission of these items for the pre-1970 period, when they are apparently not available, should not cause large discrepancies in the table.

[12] Sections V and VI prepared by Migdon Segal, Science Policy Research Division.

TABLE 1.—CIVIL NUCLEAR ENERGY R. & D. FUNDING, FISCAL YEARS 1948–79

[Figures in millons of dollars]

Fiscal years	Funding	Fiscal years	Funding
1948	[1] $54.1	1965	$207.4
1949	17.0	1966	193.4
1950	27.6	1967	205.8
1951	40.5	1968	242.2
1952	62.8	1969	218.7
1953	92.4	1970	[3] 281.3
1954	87.6	1971	322.9
1955	[2] 58.1	1972	387.0
1956	79.7	1973	467.5
1957	77.2	1974	594.6
1958	110.9	1975	783.3
1959	135.5	1976	832.9
1960	167.3	Transition quarter	271.8
1961	179.4	1977	1,164.4
1962	188.6	1978 (estimate)	1,409.3
1963	194.8	1979 (estimate)	1,341.3
1964	207.6		
		Total	10,704.9

[1] Includes civil and military reactors (1948–54).
[2] Includes civilian reactor development only (1955–69).
[3] Includes all civilian nuclear R. & D. (1970–79).

VI. BENEFITS TO NUCLEAR POWER DERIVING FROM THE PRICE-ANDERSON ACT

The Price-Anderson Act, concerning liability and indemnification for nuclear power facilities, was enacted in 1957. It was extended in 1965, and then modified and extended in December, 1975. It currently runs until 1987.

The Act was intended to aid the growth of commercial nuclear power by removing the risk to the operator of the power facility of unlimited liability claims in the event of a catastrophic nuclear accident. It was recognized that nuclear power presented unique problems in this regard, as a small but finite probability exists of an accident occurring that would have a devastating effect on the area surrounding the nuclear plant. The private insurance companies could not take on the task of insuring against nuclear accidents since they could not calculate the probability of such an accident without operating experience with nuclear power reactors. Therefore it was felt that Government intervention was necessary if nuclear power were to have a chance of commercial development.

In its original form, the Price-Anderson Act stipulated that the maximum liability for a nuclear accident should not exceed $560 million. Of that total, private insurance would supply $60 million and the Federal Government $500 million.

In the 1975 revision, the Government's obligation, which had already decreased to $420 million, was further decreased and is expected

eventually to be eliminated. This was done by making the owners of each operating reactor liable for $5 million in the event of a catastrophic nuclear accident at any other reactor. The prospective $5 million payments are known as "retroactive premiums." These premiums would be paid by the reactor owners in the event of an accident exceeding in liability the $140 million now paid by private insurance. Since there are now (in late 1978) 71 reactors operating, this would amount to $355 million in retroactive premiums. Added to the $140 million private insurance pool, $495 million is accounted for, with the Federal liability reduced to $65 million. When another 13 reactors begin operation, the Government's indemnity will be eliminated altogether. The limit on liability will then rise from $560 million as additional reactors come into service beyond that point.

The benefit to the nuclear industry from the Price-Anderson Act can be divided into two sections; benefits from the liability limitation and benefits from Government indemnification of liability coverage. The benefit from liability limitation cannot be quantified, since no accidents have occurred that would have exceeded the $560 million limit, and in fact no accidents involving the public at all have occurred at a nuclear facility. However, it is generally agreed that development of commercial nuclear power would have been halted or greatly slowed by the absence of such a liability limitation. Therefore the advantage to the industry, while not quantifiable, is real.

The benefit from Government indemnification can be estimated, using a 1975 GAO study and CRS calculation (see appendix). The Federal Government had collected about $10 million in fees by August, 1977, which amounted to about $90,000 per power reactor per year. The cost of private liability insurance, if it were available, would have been roughly $190,000 per reactor per year. The benefit to the industry then, was approximately $100,000 per reactor per year, or about $11 million in total "subsidies" to the industry. This Government indemnity is expected to disappear within the next several years, as more commercial nuclear reactors go into service.

For a more detailed discussion of this matter, see "Direct and Indirect Benefits of the Price-Anderson Act for Commercial Nuclear Power," by Carl Behrens, CRS, which appears in Appendix III.

VII. FEDERAL ENERGY-RELATED ENVIRONMENTAL SAFETY R&D[13]

The Energy Reorganization Act of 1977, Public Law 93–438, authorized the Administrator of Energy Research and Development (ERDA) to establish programs to minimize the adverse environmental effects of energy development and utilization. It further directs that these programs utilize research and development efforts supported by other Federal agencies to promote faster cooperation and avoid unnecessary duplication.

The Federal Nonnuclear Energy Research Development Act of 1974, Public Law 93–577, requires that ERDA submit to Congress a comprehensive energy research, development, and demonstration plan and a comprehensive nonnuclear energy program on an annual basis. The report is to include the relative financial contribution of agencies of the Federal Government.

---

[13] Prepared by Joseph P. Biniek, Environmental and Natural Resources Policy Division.

The following data, abstracted from the ERDA Inventory of Federal Energy-Related Environment and Safety Research for FY 1976, identifies research funding in fossil general, coal, nuclear general and fission categories.

The data in Table II show the overall pattern of funding by the various agencies involved. Specific coal related research amounts to $67.8 million, while an additional $31.3 million is expended for fossil general, i.e. technology not specifically applicable to any fossil fuel. Nuclear general expenditures reached $73.5 million in FY 1976 (not specifically fission or fusion) with an additional $103.4 million for nuclear technology.

Table III presents Biomedical and Environmental Research funding (BER). This category includes: (1) Characterization, Measurement and Monitoring; (2) Environmental Transport, Physical and Chemical, Processes and Effects; (3) Health Effects; (4) Ecological Processes; and (5) Integrated Assessment. Coal-BER funding was $30.1 million in FY 1976 and nuclear fission-BER funding was $34.6 million.

Table IV presents data on projects that were designated entirely or partially to environmental control. The funding for environmental funding for coal far exceeds that of nuclear fission ($37.6 million for coal and $0.7 million for nuclear). In contrast Table V shows that considerably more funds were used for safety in the nuclear technology than for coal ($68.1 million in contrast to $0.2 million for coal).

A caveat must be attached to the data. As stated in the Executive Summary of the Inventory:

"This Inventory, although as complete as possible, is undoubtedly deficient in reporting all Federally sponsored energy-related environment and safety research. It is difficult for an agency to determine what research is energy related or to report relevant minor parts of larger projects that marginally fit the criteria for inclusion."

TABLE II.—ENERGY TECHNOLOGY CATEGORY FUNDING BY FEDERAL AGENCY, FISCAL YEAR 1976

[In millions of dollars]

Agency	Technology				
	Fossil general	Coal	Nuclear general	Fission	Fusion
DOA	4.7	2.1	0.2		
DOC:					
OEA					
NBS	.4	(1)	.7	0.3	(1)
NOAA	.7	.1	.6		
DOD	.1				
HEW:					
NIOSH	.4	.7			
NIEHS	2.5	.1	.3		
NCI	2.5		.4		
HUD					
DOI:					
FWS	.7	.1			
BLM					
USGS	.6	6.8	1.6	1.7	
RECLAM					
BPA	(1)	.1	.1		(1)
DOT					
EPA	6.7	34.8	.2		
ERDA	9.7	15.1	60.6	34.7	2.1
FEA	.3	.1	(1)		
NSF/RANN	.4	.2			
NASA	.2	.4			
NRC			7.9	66.5	
TVA	1.3	7.2	.9	.2	
Total	31.3	67.8	73.5	103.4	2.1

[1] Less than $50,000.

TABLE III.—BIOMEDICAL AND ENVIRONMENTAL RESEARCH FUNDING (ENERGY TECHNOLOGY BY FEDERAL AGENCY), FISCAL YEAR 1976

[In millions of dollars]

Agency	Technology: Fossil general	Coal	Nuclear general	Fission	Fusion
DOA	1.8	1.5	0.1		
DOC:					
OEA					
NBS	.4	(1)	.6	0.3	(1)
NOAA	.7	.1	.6		
DOD					
HEW:					
NIOSH	.3	.6			
NIEHS	2.5	.1	.3		
NCI	2.5		.4		
HUD					
DOI:					
FWS	.7	.1			
BLM					
USGS	.5	4.0	1.6	1.0	
RECLAM					
BPA	(1)	.1	.1		(1)
DOT					
EPA	3.2	7.1	.2		
ERDA	9.6	12.7	28.1	30.1	1.7
FEA	.3	.1	(1)		
NSF/RANN	.4	.2			
NASA	.2	.3			
NRC			1.6	3.0	
TVA	.5	3.1	.9	.2	
Total	23.7	30.1	34.5	34.6	1.7

[1] Less than $50,000.

TABLE IV.—ENVIRONMENTAL CONTROL TECHNOLOGY FUNDING (ENERGY TECHNOLOGY BY FEDERAL AGENCY), FISCAL YEAR 1976

[In millions of dollars]

Agency	Technology: Fossil general	Coal	Nuclear general	Fission	Fusion
DOA	2.9	0.5	0.1		
DOC:					
OEA					
NBS					
NOAA					
DOD	.1				
HEW:					
NIOSH					
NIEHS					
NCI					
HUD					
DOI:					
FWS					
BLM					
USGS		2.8			
RECLAM					
BPA		(1)			
DOT					
EPA	3.5	27.7	(1)		
ERDA	.1	2.4	30.5	0.7	0.2
FEA					
NSF/RANN					
NASA		.2			
NRC			1.3	(1)	
TVA	.8	4.0			
Total	7.4	37.6	32.0	.7	.2

[1] Less than $50,000.

TABLE V.—OPERATIONAL SAFETY FUNDING (ENERGY TECHNOLOGY BY FEDERAL AGENCY), FISCAL YEAR 1976

[In millions of dollars]

Agency	Technology				
	Fossil general	Coal	Nuclear general	Fission	Fusion
DOA					
DOC:					
OEA					
NBS			[1]	[1]	[1]
NOAA		[1]			
DOD					
HEW:					
NIOSH	0.1	0.2			
NIEHS					
NCI					
HUD					
DOI:					
FWS					
BLM					
USGS	[1]			0.7	
RECLAM					
BPA					
DOT					
EPA					
ERDA	.1	[1]	2.0	4.0	0.2
FEA					
NSF/RANN					
NASA					
NRC			5.0	63.4	
TVA					
Total	.2	.2	7.0	68.1	.2

[1] Less than $50,000.

VIII. GOVERNMENT PURCHASING PROGRAMS [14]

There is no purchasing program for coal. The Department of Energy does operate, however, a loan guarantee program for those who produced less than one million (m) tons of coal in the preceding year, did not have gross revenues in excess of $50m, did not own an oil refinery, and did not produce more than 300,000 barrels of crude oil. The guarantee cannot exceed 80 percent of the loan or cost of the project, whichever is less, up to a maximum of $30 m.

Uranium, on the other hand, was part of a virtual Government monopoly from 1942 through the 1960's. At present, the government operates three enrichment plants but is not active in other parts of the fuel cycle.

In the early days of the nuclear age, the Atomic Energy Commission made long-range purchase commitments. These were a major tool in the effort to develop production capability. This program was phased out between 1958 and 1970. In addition, as of January 1, 1969, electric power producers were permitted to buy uranium directly from miners. The uranium market is now unregulated.

IX. COAL, URANIUM, AND THE PUBLIC LAND LAWS

Uranium is produced exclusively in States west of the Mississippi River, while coal is produced throughout the United States. Thus, some coal and all uranium is impacted by the land laws of the U.S. since virtually all of these lands are located west of the Mississippi. There are three general classes of land on which uranium and

[14] Sections VIII and IX prepared by Alvin Kaufman and Susan J. Bodilly, Office of Senior Specialists.

coal production occurs. These include Indian land, acquired land, and public domain.

On Indian lands the decision as to dispoasl is made by the tribe holding title to the land, and can be considered as a private transaction.

Mineral rights on acquired lands are disposed of through competitive bidding. On the public domain, however, the disposal systems for uranium and coal diverge. Coal land is made available under the various leasing acts and the coal leasing amendments of 1975. Uranium, on the other hand, is covered under the Mining Law of 1972. These two systems are quite different, and some background is essential.

1. Uranium [15]

The major uranium producing states in 1977 were New Mexico and Wyoming. These two yielded an estimated 77 percent of our uranium output. Some 14 firms produced 97 percent of the total of the primary mine production.

Underground mining accounted for 42% of the uranium ore mined in the United States, in 1977, but because the grade of ores was generally higher than those produced by surface mining, it was responsible for 50% of the U_3O_8 output. Open-pit mines accounted for most of the remainder. There is, however, some in situ production of uranium from Wyoming and Southeastern Texas, heap leaching operations in other parts of the country and as a by-product of other mining activity primarily from Florida phosphate operations. An estimated 48% of our reserves mineable at $30 per ton (as of 1/1/77) are located on the Public Lands administered by the Bureau of Land Management (BLM).

Virtually all of these lands are disposable under the Mining Law of 1972. Under this act no permit is required for prospecting. A prospector, when he finds what he believes would justify a prudent man to make a further expenditure, may stake a claim according to the procedures outlined by the Bureau of Land Management. Notice of the claim is filed with the BLM as well as the local land office. He pays the Bureau of Land Management a filing fee of $5.00. From that time forward, a valid claim can be maintained as long as $100 in improvements is completed each year (assessment work). Statements of the assessment work completion are filed each year with the Bureau of Land Management. There is no filing fee.

Unpatented claims may be worked. The prospector is permitted to use that part of the surface required for mining and may construct necessary structures. The Federal Government retains the management of the surface and surface resources.

If full title is desired, and assuming the claim meets legal requirements, a patent (title) can be obtained. To do so, the claim must be surveyed by an approved mineral surveyor, and a notice of intent published over a 60 day period. A $25.00 filing fee is collected by BLM. Assuming all goes well, the claim can be purchased at the rate of $5.00 per acre for lode claims and $2.50 for placer claims. A lode claim comprises approximately 10 acres, and a placer claim 20 acres. An estimated 3 million acres have been patented under the Mining Law,

[15] Except as otherwise noted, this section is based on; A. BLM, "Staking a Mining Claim on Federal Lands," U.S. G.P.O., 1978, IS §2–78. B. BLM, "Patenting a Mining Claim on Federal Lands," U.S. G.P.O. 1978, IS §4–78. C. Li, Ta M. and John D. Wiebmer, "Uranium Mining in the U.S.," Mining Engineering, October 1978, pp. 1405–1410.

with the bulk occurring between 1880 and 1920. In the 1949–78 periods, an average of less than 100 claims annually have been patented for all minerals. The recent peak, reaching as high as 160 claims, was reached in the 1953–62 period when the search for uranium was at its highest. In the 1970–78 period, approximately 30 claims have been patented each year. The decline is attributable to the depletion of the number of easily found deposits, exclusion of various minerals from the mining law, intensified enforcement of the law, establishment of standards for determining claim validity, and land withdrawals.[16]

It should be noted that prior to 1976, claim locators were not required to file a claim notice with BLM. As a consquence, the Federal Government often had no idea who controlled what on the Public Domain. Also, since no royalties were payble, it had no idea of the quantity of mineral produced, their value or costs.

Costs fall into two categories; those direct costs incurred to produce uranium and those incurred by society. Various estimates of direct costs are available. An ore deposit containing a reserve of 2 million pounds in a one foot thick vein at a depth of 150 feet would have a total cost per pound of U_3O_8 recovered of $28.12, including capital and operating cost, and would earn a discounted cash flow return on investment of 14.9 percent. Open pit mining cost is estimated at $3 per short ton, stripping cost at $1.38 per cubic yard, mill operating costs vary between $9 and $12.75 per short ton depending on the through put of the mill; capital costs very between $15 m and $32 m, again depending on the size of the mill and the grade of the ore to be recovered.[17]

An alternative set of cost estimates indicates that, as of January 1976, open-pit mining costs were $1.60 and underground costs were $8.16 per pound of U_3O_8. Adding transportation, milling and royalties gives an operating cost of $5.02 for open pit and $11.83 for underground per pound U_3O_8. Capital and operating costs together totaled $10.43 for open-pit and $17.65 for underground. Total cost per ton of ore is computed at $29.88 for open-pit and $49.47 for underground. These are based on an ore grade of 0.15% U_3O_8 2000 tons of ore produced per day, mill recovery of 94%, stripping ratio at 24 to 1, underground mine depth at 750 feet.[18]

Indirect costs are harder to measure, and in any case are outside the scope of this paper. An excellent summary is available, however, in the Senzel article cited earlier (p. 19–23), together with a discussion of the perceived issues and alternatives to the Mining Law (p. 47–53).

2. Coal [19]

The Federal coal leasing system is undergoing extensive change as a consequence of administrative, legislative, and judicial action. At present, coal leasing has been stopped by a court injunction issued as a

---

[16] Senzel, Irving, "Revision of the Mining Law of 1872," Committee on Energy & Natural Resources, U.S. Senate, April 1977, Publications No. 95–11, pp. 55–57.

[17] Borkett, John J. and Carl E. Gerity, "An Economic Analysis of Open-pit and in Situ Mining," Oct. 1978, Mining Engineering, p. 1420–122.

[18] Patterson, John A., "U.S. Uranium Production Outlook," presented at the Atomic Industrial Forum, Interntl. Conf. on Uranium, Geneva, Switz., Sept. 14, 1976, Fig. 13.

[19] A. Krulitz, Leo M., "Management of Federal Coal" presented to Rocky Mountain Mineral Law Institute, Vail, Colo., July 20, 1978. B. Lindahl, D. M. & D. A. Thompson, "Federal Coal Leasing Policies & Regulations," CRS for Committee on Energy & Natural Resources, U.S. Senate, Pub. 95–77, Jan. 1978, p. 160.

consequence of the *National Defense Council* v. *Royston Hughes* decision in June 1978.

Through approximately 1976, Federal coal leasing was administered under the Mineral Leasing Act of 1920. Under that Act, the Secretary of Interior was responsible for leasing and prospecting on Federal lands. Prospecting permits were issued for a \$10.00 filing fee and an annual rental of \$0.25 an acre. The permit could be renewed after the initial two-year period for an additional two years. In the event the permit holder found coal in commercial quantities, he was entitled to a preference right lease on a portion of the prospecting permit holding. These preference right leases required payment of royalties and rental fees equalling the resource value of the coal. In addition, one could obtain a lease through competitive bidding.

It was charged, however, that the system was used by speculators to tie up large blocks of Federal coal lands for future sale. To illustrate, between 1920 and 1945 some 80,000 acres were leased, from 1945 to 1970, 700,000 additional acres were leased. The bulk of these leases were awarded in the 1960s. The average size of a lease also increased, rising to 2,173 acres during the 1966 to 1970 period. This was 400% greater than the average lease in the 1940–49 period. It was estimated that by 1970 there was enough coal under lease to supply 250 m tons of coal per year, but production amounted to only 7.4 m tons a year.

As of 1976, some 208 leasees held 467 federal leases covering 682,000 acres. Of these, approximately 217 were preference right leases. Of the total number of leases, 239 have never produced with no plans to produce, 79 have no record of past production but anticipate production in the future; the remainder have produced in the past and anticipate producing in the future. Thus some ⅔ of the leases in existence in 1976 had never produced any coal.[20] Apparently the lands were being held rather than developed.

On August 4, 1976, the Federal Coal Amendment Act of 1975 was passed over President Ford's veto. This Act prohibits the speculative holding of coal lands and requires production of commercial quantities of coal in 10 years or termination of the lease. It also requires competitive bidding on all leases with a minimum royalty of 12.5% for surface mining and 8% for underground. Pending preference right leases are not subject of competitive bid, but are subject to fair market value payments for royalties and rentals. In addition, permits already in existence were allowed to continue. Exploration licenses were made available under the act for a \$250 filing fee. These grant the right to explore, but not the right to lease. A deferred bonus can be granted for 50% of the acreage leased by BLM in a year.

In reality, however, actual leasing came to a virtual standstill in 1971 as a consequence of a study by the BLM that found inadequate environmental safeguards and lack of production on leases issued prior to 1970. In 1973 this informal policy was formalized. There have been no further leasing, prospecting or preference right agreements issued, except as discussed below.

The exception to the moratorium constitutes emergency short term leases issued to permit leasing when reserves were needed to continue production at an already producing site.

---

[20] BLM, "Coal, An Analysis of Existing Federal Coal Leases," U.S. Dept. of Interior, March 1976.

The leasing moratorium was suspended after the Department of Interior issued the coal programmatic environmental impact statement to comply with NEPA and to assure that environmental concerns would be taken into account in coal leasing (1975). In July 1977, the Department of Interior announced a commitment to withhold all new leasing until it had completed a comprehensive review of its program as a result of intense public criticism aud court orders. This review was scheduled to be completed by June 1979.

The Natural Resources Defense Council took the Department to court in October 1975, because of its preceived inadequacies in the environmental statements. The court ordered in 1977 that there be no further new coal leasing until a complete impact statement had been provided with the following exceptions; when a lease is required to maintain existing mining operations or to meet a previously existing contract; when coal to be leased would be more costly to mine later or would cause additional environmental damage if mined at a later date; or when a lease is offered in exchange for an old lease that could not be mined in compliance with NEPA or for certain specific applications subject to competitive bid. These leases can only be for 8 years and production per year from these leases cannot exceed the current production or contracted production. In July 1978 this order was slightly revised to define the current program.

In December 1978, the Department of Interior scheduled the issuance of a draft programmatic environmental impact statement. The draft will require review and comments under the court decision. It is anticipated that by June 1979, the Secretary will determine the permanent coal leasing program.

As a consequence of this history, very little leasing has occurred since 1971. In 1978, approximately 8 leases will be issued under the emergency short-term ruling. In addition, some 20 of the least environmentally damaging preference right leases will be processed to the point of issuance. Current procedures for leasing are summarized in Appendix 1. It should be emphasized that these are subject to change. According to BLM sources it can take from 311 to 411 days to process an application. Under the current temporary system, a leasee pays an arbitrary bonus of $25 per acre to cover the cost of the sale and processing. In those instances where the deferred bonus is permitted the lessee pays in equal one year installments over a 5 year period.

Royalty payments under the Coal Leasing Amendments Act are set at a minimum of 12½ percent of gross value for surface mining, and 8 percent for underground mining. Under the current system the royalties are adjusted to reflect the resource economic value taking into account the $25 per acre bonus. Royalty payments in recent years tend to be relatively high while the bonus is relatively low. Rentals are collected at the rate of $3.00 per acre per year over the term of the lease. In the past, a rental was charged only until the mine became operational. In addition, a bond is required to insure payment of the royalty and rental fees with the amount of the bond equivalent to the estimated 6 months royalty and rental payments. The bond can be filed in cash or securities, but the Government pays no interest on this deposit. The leasee, therefore usually files a Corporate Surety Bond in order to avoid large cash payments. In addition. in the near future surface reclamation bonds will also be required.

These bonds will be determined after the leasing process and upon submittal of a mining plan to the Department.

The Leasing Amendment Act also provides that those leases issued after the enactment date must be productive within ten years. Because of the moratorium, few leases have been issued since the date of the Act. Those leases currently in effect generally are not subject to this production constraint. A review of a lease issued before 1976 takes place 20 years after enactment and thus the bulk of the leases will not be reviewed until after 1980.

Industry, supported somewhat by the Department of Interior, has claimed that production on some of the leased land is impossible as a consequence of new environmental constraints. As a result, several attempts have been made to give the Secretary of Interior power to grant lease preferences for new leases to those who cannot produce from their current property because of these constraints. Thus the status of the coal leasing program is one of considerable uncertainty, pending the completion of studies, public hearings, and so forth. A new leasing system will eventually be developed that will meet the court mandate, as well as the mandate of the Coal Leasing Amendments Act of 1975.

Despite these efforts, the coal leasing program is still under attack, both as a giveaway and as unnecessary. A recent article indicated a 77 m ton surplus of western coal in 1980 and 95 m ton surplus in 1985, compared with expected demand. The analyst was quoted as saying his clients should not "become too agitated over the environmental/legislative morass surrounding roadblocks to Western leasing. There is too much." [21]

Another study indicated that a substantial increase in western output could be supported without additional leasing. This paper stated that only 14% of Federal leases and 0.7% of State leases are now in production. It further reported the average paid was $17.79 per acre for Federal leases.[22]

Much of the above relates to a program that is in the process of change, and may well be designed to push the new program in a specific direction. In any case, the merits of the new program cannot be evaluated until it has been unveiled.

3. The subsidy impact

One could take the view that since uranium and coal are both energy minerals, producers of these should earn equivalent rates of return as a consequence of the operation of the public land laws, all other things being equal. The rate of return, of course, would have to be adjusted for the perceived risks of the two different operations. That is, there are risks taken by a producer of a mineral commodity in terms of market availability, price and so forth, as well as geologic risks. These must be compensated for in the rate of return. Thus, the uranium producer might properly earn a higher rate of return than the coal producer or vice versa, depending on risk perception.

In order to compute this rate of return, data for typical coal and uranium operations could be developed showing revenues and costs.

---

[21] "Analyst Sees Too Much Coal for 1985 Demand, Leasing as Unnecessary," Electrical Week, September 25, 1978.

[22] "Leasing Program a Giveaway," Energy Digest, Nov. 30, 1978, p. 367–8.

For example, some cost data is presented in the uranium section of this report. Coal data is available also.[23]

This, however, would not be a useful exercise because of the uncertainty surrounding the issuance of the coal leasing system. Current procedures are a temporary and ad hoc arrangement. The earlier system is no longer applicable. Further, costs would reflect the land law conditions existing prior to the *Royston Hughes* court decision. These reflected the economic circumstances of those days and thus are not applicable to the situation today.

As a consequence, we have made no effort to quantitiatively compare uranium and coal land disposal systems. We have, instead set out the operation of the systems and the relative fees levied.

X. THE TAX TREATMENT OF ELECTRICITY GENERATED FROM COAL VERSUS NUCLEAR POWER SOURCES [24]

This section assesses the extent to which the relative costs of generating electricity from coal versus nuclear power are affected by differential treatment under the Federal income tax. There are two ways in which the tax code can have different economic effects on different industries or technologies within an industry. First, the same tax provision may have different affects on different industries or technologies because of their different economic characteristics. For example, the investment tax credit may have different economic effects on industries if the industries are characterized by different average useful lives of their capital assets.[25] The second way in which the tax code may differentially affect industries or technologies is if separate tax provisions apply, for example, different tax rates or dissimilar rules governing deductions. This analysis concentrates only on the second type of differential tax effect on coal versus nuclear generation of electricity (analysis of the first type of differentiation would require a much more detailed study).

There are two differences in the treatment of electricity generation from coal and nuclear fuel sources under the Federal income tax. The first is the depletion allowances available on the fuel sources when they are mined. Depletion is a tax deduction allowed against income from extraction of minerals, oil or gas, or timber from property. The depletion allowance serves a purpose similar to depreciation: it allows the tax-free recovery of invested capital from the gross income produced by the extraction, and simultaneously, it provides for the matching of income from the asset with the cost of "using up" the asset. However, in the case of depletion, as opposed to depreciation, two types of deduction are allowed by the tax code. Cost depletion is similar to depreciation in concept; an amount is deducted from income each year which corresponds to the amount of the capital asset used up in the production process, and aggregate deductions over the life

[23] See "Basic Estimated Capital Investment & Operating Costs for Coal Strip Mines" (I.C. 8703) and "Basic Estimated Capital Investment & Operating Costs for Underground Bituminous Coal Mines" (I.C. 8682A), both by the Bureau of Mines, U.S. Dept. of Interior, 1976.

[24] Prepared by Donald W. Kiefer, Economics Division.

[25] See: Sunley, Emil M., Tax Neutrality Between Capital Services Provided by Long-Lived and Short-Lived Assets, OTA Paper 10, Office of Tax Analysis, U.S. Treasury Department, November 1976. 17 p.

of the asset may not exceed its original cost. However a second type of depletion allowance, percentage depletion, is also available on many types of depletable resources. Under percentage depletion, a stated percent of the gross income from the extractive activity is allowed for depletion, and there is no limitation that aggregate deductions over the life of the asset may not exceed its original cost.[26] Percentage depletion is usually much more beneficial to the extractive enterprise than cost depletion. The mining of coal and uranium both receive percentage depletion allowances; the percent is 10 percent for coal and 22 percent for uranium (see I.R.C. sec. 613(b)).

The second difference in the tax law in the treatment of coal versus nuclear electricity generation is in the amortization of the generating plants. The tax code specifies both the types of depreciation method which may be used by taxpayers and the depreciable lives over which capital assets may be depreciated. Both coal-fired and nuclear generating plants may use accelerated depreciation methods, however their permitted depreciable lives are different. Regulatory authorities generally regard 30 years as a reasonable estimate of the useful life of both coal-fired and nuclear generating plants, however for tax computations, coal-fired plants may be depreciated over a 22.5 year period and nuclear plants over a 16 year period (see Reg. sec. 1.167 (a)–11). The ability to depreciate a capital asset over a shorter time period provides a financial benefit because the invested capital may be recovered more quickly.

Accurate assessment of the impact of these differences in tax treatment on the relative costs of coal versus nuclear electricity generation would require detailed financial analysis on a plant-by-plant basis. Such an undertaking is not feasible in this report. However, average impacts can be calculated as an illustration of the methodology and to provide aggregated policy information. Table VI presents Department of Energy (DOE) data on generation costs on a per kilowatt-hour (Kwh) basis from coal and nuclear generating plants. The fuel and operation and maintenance costs are averages of actual data reported to DOE; the capital costs are estimated by a methodology explained in Appendix II.

To adjust the fuel cost data to account for the different percentage depletion allowances on coal and uranium it is first necessary to determine what amount of the fuel costs shown in Table VI are attributable to ore costs, since the fuel costs in the table represent costs of delivered fuel to the utilities. While the proportion varies substantially from one part of the country to another, on a national average basis the price of coal at the minemouth represents about 68 percent of the total delivered price of coal to electric utilities.[27] The cost of uranium ore, on the other hand, appears to be about 45 percent of the total cost of nuclear fuel.[28]

---

[26] There is, however, a limitation that the percentage depletion deduction may not exceed 50 percent of taxable income from the extracting activity computed without regard to the depletion allowance.

[27] Based on 1977 data provided by DOE: National average price of a ton of coal delivered to electric utilities, $20.37; average transportation cost per ton, $6.51.

[28] Perl, Lewis U., Statement, in Hearings before a Subcommittee of the Committee on Government Operations on Nuclear Power Cost, House of Representatives, 95th Congress, 1st Session, Part 1, September 12, 13, 14, and 19, 1977. Table 8, p. 694.

TABLE VI.—NUCLEAR AND FOSSIL-FUEL GENERATING COSTS—NATIONAL AVERAGE FOR 1977

[Mills per kilowatt-hour]

Costs	Nuclear	Coal
Fuel (actual)	2.85	9.40
Operation and maintenance (actual)	2.46	1.68
Production (actual)	5.31	11.08
Capital (estimated)	9.15	6.18
Total generating (estimated)	14.46	17.26

Notes: 1. Costs are based on utility data reported to the DOE on 45 nuclear plants (totaling 62 units) and 34 multiunit coal-fired plants.
2. Production costs (fuel plus O. & M.) are averages of actual costs reported by the utilities. Capital costs (and therefore generating costs also) are estimated, based on assumed fixed charge rates and reported actual investment costs.

Source: "Update, Nuclear Power Program Information and Data," Division of Nuclear Power Development, U.S. Department of Energy, June 1978, p. 34.

Second, it is necessary to estimate the impact of the percentage depletion allowances on the ore costs. The relationship between the observed price for a mineral and its price in the absence of a percentage depletion allowance can be represented by the following equation:[29]

$$P_o = P_a - P_o \cdot D_e \cdot t \cdot p$$

Where: P_o = observed price
P_a = price in the absence of depletion allowance
D_e = depletion allowance
t = tax rate
p = portion of the tax benefit from depletion passed on through lower prices

This relationship can be rewritten as follows to provide a formula for estimating P_a:

$$P_a = P_o \cdot (1 + D_e \cdot t \cdot p)$$

Table VII shows adjustments to the fuel costs in Table VI using the above formula and the assumption that 75 percent of the tax benefits from the percentage depletion allowances are reflected in lower prices (the pass-through would not be 100 percent unless demand were perfectly price insensitive). As the table shows, despite the higher depletion allowance on uranium ore, the cost advantage of nuclear fuel over coal would actually be greater in the absence of the tax benefits. The reason is that the larger percentage depletion for uranium applies to a much smaller base than the coal depletion allowance.

[29] Strictly speaking, only the excess of percentage depletion over cost depletion should be treated as a tax benefit. However, for simplicity the entirety of the percentage depletion allowance is treated here as a tax benefit. The overstatement should be minimal.

TABLE VII.—ADJUSTMENT OF FUEL COST ASSOCIATED WITH COAL AND NUCLEAR ELECTRICITY GENERATION TO REMOVE THE TAX BENEFITS FROM PERCENTAGE DEPLETION ALLOWANCES

[Mills per kilowatt-hour]

	Nuclear	Coal	Difference
DOE fuel cost data	2.85	9.40	6.55
Cost of ore	1.28	6.39	
Adjusted ore cost	1.38	6.62	
Difference	.10	.23	
Total adjusted fuel cost	2.95	9.63	6.68

Source: Author's estimates as explained in text.

The other provision of the tax system which differentiates between coal and nuclear electricity generation regards the tax depreciable lives of the generating plants. Different tax depreciable lives affect the capital costs associated with owning assets, with shorter depreciable lives reducing the capital costs. Since nuclear plants may be depreciated over a 16-year period for tax purposes whereas coal plants may be depreciated over no shorter period than 22.5 years, the capital cost reduction resulting from shorter tax depreciable lives is greater for nuclear generating plants than coal plants. Using a methodology which is representative of practices in the utility industry for calculating levelized capital cost estimates (the methodology is detailed in the appendix) it is estimated that in the absence of shorter tax depreciable lives, the capital cost estimates for coal-fired generating plants would be 2.7 percent higher and those for nuclear plants would be 6.6 percent higher. These adjustments are shown in Table VIII.

TABLE VIII.—ADJUSTMENT OF CAPITAL COSTS ASSOCIATED WITH COAL AND NUCLEAR ELECTRICITY GENERATION TO REMOVE THE TAX BENEFITS RESULTING FROM SHORTER TAX DEPRECIABLE LIVES

[Mills per kilowatt-hours]

	Nuclear	Coal	Difference
DOE capital cost estimates	9.15	6.18	2.97
Adjusted capital cost estimates	9.75	6.35	3.40
Difference	.60	.17	.43

Source: Author's estimates as explained in text and app. II.

As the table reveals, removing the effects of the shorter tax depreciable lives from the capital cost estimates does increase the difference between the estimates for nuclear and coal plants, but not significantly.

46-139—79——5

The adjustments in Tables VII and VIII are combined with the DOE data in Table VI to provide adjusted estimates for total generating costs in Table IX. The table reveals that Federal income tax treatment does not have a significant impact on the relative costs of generating electricity from coal versus nuclear power sources as estimated by the Department of Energy.

TABLE IX.—ADJUSTED NUCLEAR AND FOSSIL-FUEL GENERATING COSTS FOR 1977

[Mills per kilowatt-hour]

Costs	Nuclear	Coal
Fuel	2.95	9.63
Operation and maintenance (actual)	2.44	1.68
Production	5.41	11.31
Capital (estimated)	9.75	6.35
Total generating (estimated)	15.16	17.6

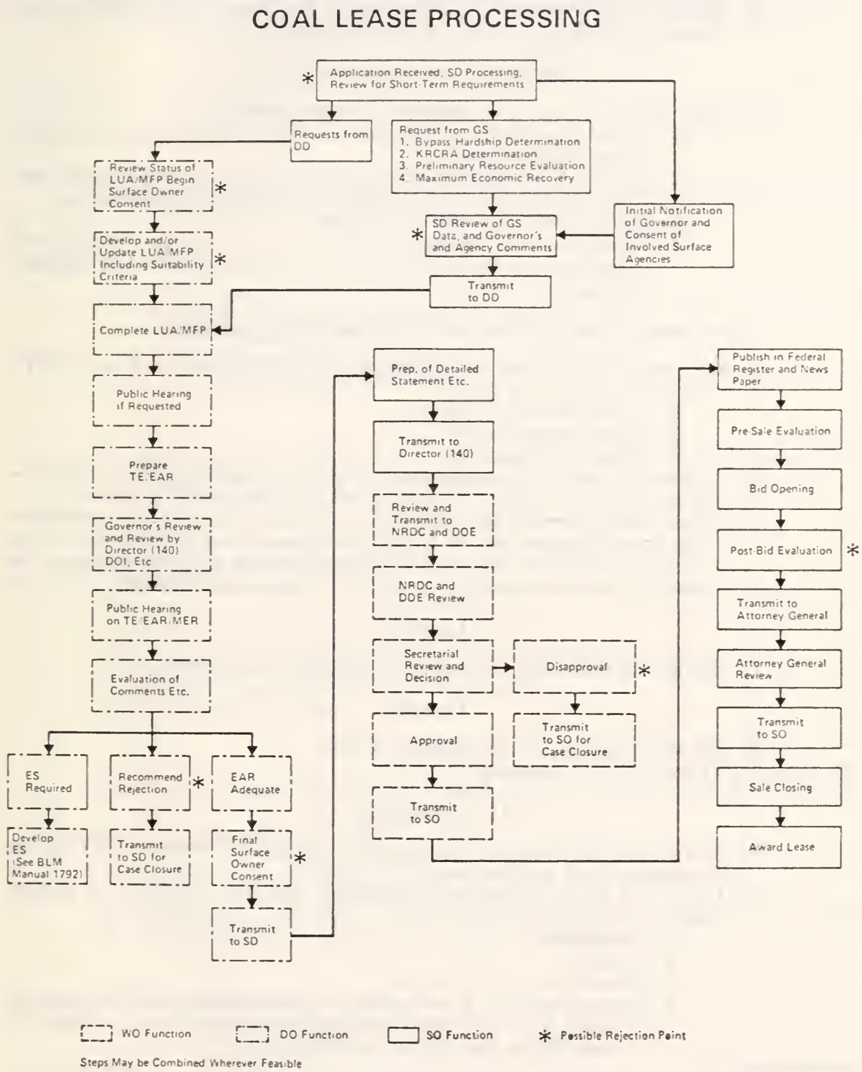
Source: Data in tables VI, VII, and VIII.

In summary, the depletion allowances on coal and uranium slightly favor coal in their overall effect on generation costs (even though the percentage depletion allowance on uranium is higher). The different tax depreciable lives on coal and nuclear generating plants provide a greater benefit to nuclear plants in reduced capital costs. However, adjusting the estimates to remove these tax-related effects does not significantly alter the relative costs of electricity generation from coal versus nuclear power sources.

Appendix I

COAL LEASE PROCESSING

CRS - A-2



I. State Office (SO) Processing:

(4–8 weeks)

A. Application received.
B. Application serialized and noted to the records.
C. Land status check:
   1. Title Report (only for acquired lands);
   2. Consent from surface agency—If negative response, reject application (surface and subsurface mining);
   3. Request DO to notify surface owner (private)—If negative response, reject application (surface mining only).
D. Obtain additional information if the application is not complete.
E. Review to determine if the short-term requirements (NRDC) have been met—If not, reject the application.

(3 weeks—once scheduled) [30]

F. Identify as bypass or hardship—Request from GS:
   1. Bypass/hardship evaluation—If GS does not concur, reject the application;
   2. KRCRA determination/documentation—If lands under application are not in a KRCRA, reject the application;
   3. Preliminary resource evaluation;
   4. Evaluation for Maximum Economic Recovery (MER)—If application does not provide for MER, reject the application.

(4–8 weeks (included as part of earlier SO processing))

G. Request from DO status of Management Framework Plan (MFP) to determine if the MFP:
   1. Is sufficient as written;
   2. Needs updating; or
   3. Must be developed.
H. Request from DO preliminary check of unsuitability criteria—Based on DO report, a decision not to lease could be issued.
I. Initial notification to the Governor—Consider Governor's comments for possible rejection (if forest lands are involved and the Governor notifies the Secretary of his objection to lease issuance, at least 6 months must be provided for Secretarial review).

(1 week)

J. Review of GS data, Governor and agency comments.

(1 week)

K. Forward case file to the District Office.

II. District Office (DO) Processing:

(1–12 months)

A. Surface owner consent—If negative response, return to SO for rejection of the application;
B. Land use plan evaluation, including detailed analysis of unsuitability criteria:
   1. Complete;
   2. Update;
   3. Develop;
   4. Public hearing, if requested by interested party—If applications does not meet the suitability standards, return the case file to the SO for rejection.

---

[30] GS has informed us that only two cases can be processed in one month.

(1 week)

C. Request GS, OSM, and other agency participation, as needed, for Environmental Assessment team.

(4–8 weeks)

D. Conduct Technical Examination (TE) and Environmental Analysis Report (EAR).

(4 weeks)

E. Notification of the Governor concerning public hearing; transmit copy of Environmental Assessment.

F. Review of Environmental Assessment by Director (140) and departmental officials as needed:
   1. Environmental Assessment is adequate;
   2. Environmental Assessment needs review;
   3. Need ES;
   4. Reject on the basis of EAR.

(1 week)

G. Public hearing on TE, EAR, MER, and method of mining (combine with requested hearing, if possible).

(1 week)

H. Evaluation of Governor's comments (transmitted from SO), Environmental Assessment, and public hearing record:
   1. Recommend ES;[31]
   2. Recommend rejection of proposed lease;
   3. Proceed with processing.

(1–2 weeks)

I. Final surface owner consent—If consent is not received, the application is returned to SO for rejection.

(1 week)

J. Case file transmitted to SO.

III. State Office Processing:

(1–2 weeks)

A. Preparation of draft detailed statement;
B. Final economic resource evaluation from GS;
C. Preparation of draft publication notice;
D. Preparation of lease;

(1 week)

E. Transmit case file with fact sheet report to Director (140).

IV. Washington Office Processing:

(1–2 weeks (transmittal) 30 days (review) 21 days (review))

A. Review and transmit the draft detailed statement and lease to DOE;
B. Notification and copy of fact sheet to NRDC.

(2–4 weeks)

C. Secretarial review:
   1. Approval;
   2. Disapproval.

---

[1] If ES is needed, time frames will be extended at least one year.

(1 week)

D. Transmit case file to State Office for case closure or further processing.

V. State Office Processing

(5–7 weeks)

A. Publication of sale notice:
1. Federal Register;
2. Local newspaper.

B. Pre-sale evaluation;

C. Bid opening;

(1 week)

D. Bid evaluation (including fair market value):
1. Acceptable bid sale;
2. No acceptable bid, reject the application.

(30 days (review))

E. Letter to the Attorney General for anti-trust review (copy of letter to Director (140)).

(30 days)

F. Sale closing:
1. Present lease for signature;
2. Bonding;
3. Balance of bonus bids;
4. Payment of advertising costs;
5. First year's rental.

G. Award lease

Appendix II

THE IMPACT OF DIFFERENT TAX DEPRECIABLE LIVES ON ESTIMATES OF CAPITAL COSTS PER KILOWATT-HOUR OF ELECTRICITY GENERATED FROM COAL VERSUS NUCLEAR FUELED UTILITY PLANTS

(Prepared by Donald W. Kiefer, Economics Division)

Department of Energy (DOE) estimates of capital costs per kilowatt-hour of electricity generated from coal versus nuclear fueled utility plants are presented in the text of this report. The estimates are based on operating and financial data provided to DOE by the Nation's electric utilities. The question arises as to how these estimates are affected by the allowance of different tax depreciable lives for the two types of generating plants.

Capital costs per kilowatt-hour (Kwh) of electricity are estimated by the following equation:

(1)
$$C_k = \frac{K_w \cdot F}{c_a \cdot 8760}$$

Where C_k = capital costs per Kwh
K_w = original cost of the plant per kilowatt of generating capacity (including AFUDC)
F = annual fixed charge rate
c_a = capacity rate

Thus, the estimated capital cost per Kwh of electricity is calculated by multiplying the original cost of a generating plant per kilowatt of capacity by the annual fixed charge rate and dividing the result by the capacity rate multiplied by the number of hours in a year (8760).

The generating plant cost figure used in equation 1, K_w, includes an allowance for funds used during construction (AFUDC) which is the accumulated return on the capital invested in the plant over its construction period, which, in the case of utility plants, is quite protracted. This allowance reflects the practice of most utility regulatory commissions of capitalizing the return on construction expenditures rather than allowing an immediate inclusion in the rate base.

The capacity rate is a percentage which indicates the portion of the total theoretical potential annual generating capacity of the utility plant (the generating capacity multiplied by the number of hours in a year) which is expected to be actually used, on an average basis. The rate obviously reflects both demand and reliability factors. The DOE cost estimates are based on capacity rates derived from actual utility operating data each year. The 1977 estimates are based on a capacity factor of 64.6 percent for nuclear and 60.0 percent for coal generation. (Earlier data showed lower capacity rates for nuclear.)

The annual fixed charge rate is a percentage which relates the original cost of a generating plant to its annual cost during its useful life. The use of such a fixed charge rate in calculations of annual capital costs per Kwh is standard practice in the utility industry; however, there is no generally accepted methodology for calculating the fixed charge rate. The derivation of the fixed charge rate which was used in calculating the estimated capital costs displayed in Table VI in the text was not detailed in the source of those estimates. The only discussion of the fixed charge rate was as follows:

> The fixed charges were calculated based on a constant fixed charge rate (FCR), or constant percentage of the total capital cost. Discussions with several utility and trade association cost analysts have indicated considerable variance within the utility industry in the method for determining this rate. Even if the same accounting methods were used, the FCR would vary considerably from utility to utility because of different debt servicing rates, returns on equity, and tax rates. For

investor-owned utilities an average FCR of 17 percent was used, based on the following assumptions:

	Percent
Cost of debt and return on equity	8. 7
Depreciation (30-year straight line)	3. 3
Taxes, insurance and miscellaneous	5. 0
Total FCR	17. 0

Discussions with a number of investor-owned utility cost analysts in 1977 indicated that 17 percent was a reasonable average for the private industry at that time.[1]

This excerpt creates the impression that the fixed charge rate (FCR) used in the calculations is merely the result of adding the utility's cost of capital, its book depreciation rate, and its tax and insurance rates. However, such an approach for deriving the FCR would be highly inappropriate. For the FCR to serve its purpose—levelizing the capital costs over the economic life of a utility plant—it must be derived from a procedure which explicitly considers the time value of money and recognizes the various components of the capital costs associated with a utility plant.

In the absence of detailed methodological information on the derivation of the FCR used to calculate the estimates in Table VI, an alternative procedure has been employed. A methodology under development in the Department of Energy has been used to calculate FCR's for coal-fired and nuclear generating plants.[2] The methodology is still under development and therefore should not be regarded as final or representing DOE policy (in fact, different groups within DOE have different approaches to calculating the FCR under development). Nor should use of a particular procedure imply endorsement by CRS;[3] the intention is merely to use a representative methodology to examine the impact of alternative tax policies on estimates of utility capital costs.

The equation used to calculate the FCR is as follows:

$$\text{(2)} \qquad FCR = V + \frac{A}{(1-t)} \cdot \left[1 - P_v(ITC) - P_v(Sal) + P_v(In) - P_v(Dep)\right]$$

Where: V=ad valorem rate (property tax plus insurance) as a fraction of total plant cost.

t =the tax rate.

A is a multiplier for calculating the levelized payment necessary to equal a given present value over a stated time period, and is calculated by the following formula:

$$A = \frac{r_k \cdot (1+r_k)^{Ne}}{(1+r_k)^{Ne} - 1}$$

Where: r_k=the cost of capital

Ne=the economic life of the utility plant

$P_v(ITC)$ is the present value of the investment tax credit as a fraction of total plant cost, and in this formula is given as follows:

$$P_v(ITC) = r_c \cdot B$$

Where: r_c=ITC rate

B=actual historical cost of the utility plant as a fraction of total cost including AFUDC

$Pv(Sal)$ is the present value of the salvage value of the plant as a fraction of total plant cost and is calculated as follows:

$$P_v(Sal) = \frac{S_{Ne}}{(1+r_k)^{Ne}}$$

[1] Update, Nuclear Power Program Information and Data, Division of Nuclear Power Development, U.S. Department of Energy, June 1978, p. 20.

[2] The procedure and its derivation are detailed in: Borlick, Robert L., A Methodology for Simulating Powerplant Investment Decisions in the Project Independence Evaluation System, Technical Report, Pre-publication Draft, Electric Power Analysis Division, Office of Energy Source Analysis, Department of Energy, Mar. 9, 1978.

[3] For example, the equation used (see below) does not take into account the time value of the investment tax credit received on construction progress payments or of the tax deductibility of construction period interest, nor does it reflect the impact on capital costs of the alternative regulatory treatments (normalization versus flow through) of accelerated depreciation and the investment tax credit.

Where: S_{N_e}=salvage value of the plant (as a fraction of total plant cost)

Pv(In) is the present value of any interim investments required for the utility plant as a fraction of total plant cost. The principal interim investments involve pollution control devices for coal-fired plants. This value is calculated as follows:

$$P_v(\mathrm{In})=\frac{\mathrm{In}}{(1+r_k)^m}$$

Where: In=interim investment (as a fraction of total plant cost)
m=year of interim investment

P*v*(Dep) is the present value of the tax reduction which results from depreciation deductions over the life of the plant as a fraction of total plant cost. For accelerated depreciation (using the sum-of-the-years-digits method), the value is calculated as follows:

$$P_v=P_v(\mathrm{Dep})=\frac{-2\cdot t\cdot[\mathrm{r}_k\cdot Nt-1+1(1+r_k)^{-Nt}]}{\mathrm{r}_k^2\cdot \mathrm{Nt}\cdot(\mathrm{Nt}+1)}\cdot\left[B-S_{N_e}\right]^*$$

Where: Nt=tax depreciable life of the plant

For straight line depreciation the value is calculated as follows:

$$P_v(\mathrm{Dep})=\frac{t\cdot(1+r_k)^{Nt}-1}{Nt\cdot r_k\cdot(1+r_k)^{Nt}},\left[B-S_{N_e}\right]^*$$

Equation 2 was used to calculate fixed charge rates for coal and nuclear generating plants under four assumed tax depreciation policies: 1) accelerated depreciation and present tax depreciable lives, 2) straight line depreciation and present tax depreciable lives, 3) accelerated depreciation and tax depreciable life equal to economic life, and 4) straight line depreciation and tax depreciable life equal to economic life. The fixed charge rates were calculated using both acceleratd depreciation and straight line depreciation to determine whether the impact of the tax depreciable life on the FCR's was substantially affected by accelerated depreciation.

TABLE A-1.—ESTIMATES OF FIXED CHARGE RATES FOR COAL AND NUCLEAR POWERPLANTS USING ALTERNATIVE ASSUMPTIONS REGARDING TAX DEPRECIATION

	Nuclear	Coal with pollution control	Coal without pollution control
Ad valorem rate	0.035	0.035	0.035
Tax rate (Federal plus State)	[1] .505	[1] .505	[1] .505
Investment tax credit rate			
Tax dpreciable life	16	23	23
Economic life	30	30	30
Cost of capital	.087	.087	.087
Actual historical plant cost as fraction of total cost	[1] .71	[1] .77	[1] .77
Salvage value as fraction of total cost of plant	(1)	[1] .05	[1] .05
Interim investment as fraction of total cost of plant	(1)	[1] .2	[1] .2
Year of interim investment	[1] NA	[1] 15	[1] 15
Inflation rate [2]	.55	.055	.055
Calculated fixed charge rates:			
Assumed tax depreciation policy:			
(1) Tax life, accelerated depreciation	.16915	.19400	.1695
	(.9950)	(1.1412)	(.9973)
(2) Tax life, straight line depreciation	.17651	.20256	.178
	(1.0383)	(1.1915)	(1.0477)
(3) Economic life, accelerated depreciation	.17984	.19878	.17433
	(1.0579)	(1.1693)	(1.0255)
(4) Economic life, straight line depreciation	.18869	.20776	.18330
	(1.1099)	(1.2221)	(1.0782)

[1] Source of estimates: Borlick, op. cit., table 2, p. 23.
[2] The inflation rate is used to inflate the salvage value and interim investment. The rate used is taken from Data Resources, Inc., U.S. Long Term Review, fall 1978, table 1.7, p. 1.19.

Source: Author's calculations as explained in text.

*For derivations of these equations see; Kemeny, John G., Arthur Schleifer, Jr., J. Laurie Snell, and Gerald L. Thompson, Finite Mathematics with Business Applications, Prentice-Hall, Inc., Englewood Cliffs, N.J., 1962, pp. 339–344.

Table A–1 displays the assumed values used in the calculations and the results. Most of the assumed values which relate directly to the capital costs of the utility plants are taken from the DOE draft paper cited earlier.[4] The assumed cost of capital is the rate used in the capital cost estimates in Table 1 in the text. The ad valorem rate was adjusted to make the FCR's for accelerated depreciation and present tax depreciable lives as close as possible to the .17 figure used for the estimates in Table 1. The .035 ad valorem rate used is within a reasonable range; rates used in similar calculations by other analysts vary from .025 to .05.

The calculated FCR's are shown in the lower portion of Table A–1. The numbers in parentheses beneath each FCR reflect the calculated FCR as a fraction of .17, the FCR used for the estimates in Table 1. The calculated FCR's for nuclear and coal plants without pollution control devices under present policy assumptions (policy 1 in Table A–1) are close to the .17 FCR. However, the FCR for a cola plant with pollution control is considerably higher. This is not a concern for present purposes because the focus here is on the impact of the tax provisions, and the impact is very similar for both types of coal plant. The impact of the depreciable life on the FCR is also relatively unaffected by the type of depreciation (i.e., accelerated or straight line) which is assumed. Table A–2 shows FCR's assuming a 30-year tax depreciable life as a fraction or FCR's assuming the presently allowable tax depreciable life for all three types of utility plant and the two types of depreciation.

TABLE A–2.—FIXED CHARGE RATES ASSUMING 30-YR TAX DEPRECIABLE LIFE AS FRACTIONS OF FIXED CHARGE RATES ASSUMING PRESENTLY ALLOWABLE TAX DEPRECIABLE LIFE

Depreciation type	Nuclear	Coal with pollution control	Coal without pollution control
Accelerated depreciation	1.0632	1.0246	1.0282
Straight line	1.0690	1.0257	1.0291
Average	1.066	1.027	

Since the FCR enters equation 1 mutliplicatively, the average fractions appearing in Table A–2 can be used directly to adjust the capital cost estimates in Table VI in the text. Therefore, to remove the effect of the shorter tax depreciable lives, the capital cost estimates in Table VI are increased by 2.7 percent for coal plants and by 6.6 percent for nuclear plants.

[4] Borlick, op. cit. Table 2, p. 23.

Appendix III.—Previous CRS Studies

Federal Expenditures Relating to Civil Nuclear Power, Fiscal Years 1948–1974

(By Warren H. Donnelly, Specialist, Science and Technology, Science Policy Research Division Jnne 22, 1973)

From time to time the question is asked how much has the U.S. Atomic Energy Commission spent on development of commercial nuclear power. The Controller of the AEC has estimated the total accrued cost through Fiscal Year 1972 for civilian nuclear power oriented activities, including an allocation of supporting technology, at $3.5 billion but gave no details of what went into this figure.[1] To provide more detailed information on AEC funding for research and development for civilian nuclear power, I have compiled figures from the appendices to the annual budget documents of the United States. The results of this analysis are summarized in Table I. Briefly, it indicates that for the 27 fiscal years 1948–1974, the total outlay for reactor development for civil, military and space applications was $8.2 billion of which $3.7 billion was for civil power. During this same period, the AEC funded about $3.9 billion in physical research and about $1.5 billion for biological, medical and environmental research. Total AEC expenditures for this period were $47.3 billion.

Backing up Table I are six supporting tables that give details by fiscal year. This number of tables is needed because of AEC's changes in its budget format over the years.

In considering these figures, the reader should keep in mind that the amounts for fiscal years 1948–1954 were primarily for military and naval applications. The figures for subsequent years are overstated to the extent that funding for research and development in general support of nuclear power technology, advanced nuclear power systems and nuclear safety also benefited the defense applications of nuclear power. On the other hand, it seems reasonable to expect that some of the research and development funded for defense purposes produced benefits for the civilian program. Likewise, some parts of the physical research program, particularly research and development for materials, probably benefited reactor development, while the biological, medical and environmental research certainly was important for the regulation of civil nuclear power. So an undetermined part of these two programs logically could be added to the $3.7 billion estimate.

TABLE I.—FEDERAL EXPENDITURES RELATING TO CIVIL NUCLEAR POWER, FISCAL YEARS 1948–74

[In millions of dollars]

Program	Fiscal years— 1948–54 actual	1955–57 actual	1958–60 actual	1961–65 actual	1966–71 actual	1972–74 actual and estimate	Total
Reactor development total	382.0	546.8	1,043.3	2,263.3	2,669.2	1,317.1	8,221.7
Civil		(215.0)	(413.7)	(977.8)	(1,288.7)	(874.2)	(3,769.4)
Applied energy technology						34.7	34.7
Physical research	271.0	153.3	340.3	911.6	1,575.0	724.5	3,974.7
Controlled thermonuclear research [1]						112.4	12.4
Bioloigcal, medical and environmental research [2]	157.2	87.9	124.9	324.3	522.5	280.3	1,497.2
Total AEC	4,081.6	4,098.1	6,852.0	12,023.9	13,045.9	7,172.5	47,274.0

[1] CTR funding was previously included in physical research.
[2] Before fiscal year 1972 some environmental research was in the reactor development budget.

Sources: Appendixes to the Budget of the United States, fiscal years 1957–74.

[1] Letter, John P. Abbadessa, Controller, AEC, to Warren H. Donnelly, April 25, 1973.

TABLE II.—FEDERAL EXPENDITURES RELATING TO CIVIL NUCLEAR POWER, FISCAL YEARS 1948–54

[In millions of dollars, actual]

Program	Fiscal year— 1948	1949	1950	1951	1952	1953	1954	Total
Reactor development [1]	54.1	17.0	27.6	40.5	62.8	92.4	87.6	382.0
Physical research	69.6	26.2	31.1	31.5	35.6	38.4	38.6	271.0
Biology and medicine	23.8	24.9	24.9	26.5	18.9	17.6	20.6	157.2
Total AEC	672.1	293.4	310.5	400.3	753.1	763.0	889.2	4,081.6

[1] For the 1st 7 fiscal years the budget did not separate civil from defense reactor developments.

Sources: Appendixes to the Budget of the United States, fiscal years 1950–57.

TABLE III.—FEDERAL EXPENDITURES RELATING TO CIVIL NUCLEAR POWER, FISCAL YEARS 1955–57

[In millions of dollars, actual]

Program	Fiscal year 1955	Fiscal year 1956	Fiscal year 1957	Total
Reactor development:				
Civilian power reactors	27.2	42.2	54.2	123.6
Advanced development	30.9	37.5	?	68.4
Commercial ship reactors		.06	.8	.86
Civil power supporting effort			22.2	22.2
Total civil power related	(58.1)	(79.7)	(77.2)	(215.0)
Total reactor development	109.1	171.2	266.5	546.8
Physical research	44.5	49.5	59.3	153.3
Biology and medicine	28.1	28.3	31.5	87.9
Total AEC	850.1	1,476.0	1,772.0	4,098.1

Sources: Appendies to the Budget of the United States, fiscal years 1957–59.

Note: Advanxed development work also related in part to the work for nuclear power for defense purposes.

TABLE IV.—FEDERAL EXPENDITURES RELATING TO CIVIL NUCLEAR POWER, FISCAL YEARS 1958–60, ACTUAL AMOUNTS

[In millions of dollars]

Program	Fiscal year 1958	Fiscal year 1959	Fiscal year 1960	Total
Reactor development:				
Civilian power reactors:				
Government program	71.9	84.6	102.3	258.8
Cooperative demonstration program	7.2	15.5	17.4	40.1
Euratom program		2.0	0.5	2.5
General supporting R. & D	30.3	28.7	39.0	98.0
Merchant ship	1.5	4.7	8.1	14.3
Total civilian power related	(110.9)	(135.5)	(167.3)	(413.7)
Total reactor development	308.9	347.0	387.4	1,043.3
Physical research	90.5	114.6	135.2	340.3
Bibological and medical research	35.3	42.0	47.6	124.9
Total AEC	2,174.0	2,239.0	2,439.0	6,852.0

Sources: Appendixes to the Budget of the United States, fiscal years 1960–61.

Note: General supporting R. & D. also related in part to nuclear power for defense.

TABLE V.—FEDERAL EXPENDITURES RELATING TO CIVIL NUCLEAR POWER, FISCAL YEARS 1961–65

[In millions of dollars]

Program	Fiscal year— 1961	1962	1963	1964	1965	Total
Reactor development:						
Civil power reactors	77.0	80.9	77.6	74.9	74.5	384.9
Cooperative power demonstration	19.3	8.7	3.3	12.4	11.8	55.5
Euratom	.7	2.5	3.7	4.1	4.4	15.4
Merchant ship	5.7	9.1	6.4	5.2	2.0	28.4
General reactor technology	45.1	54.7	55.5	56.6	58.9	270.8
Advanced systems	20.2	17.5	24.5	25.9	27.6	115.7
Nuclear safety	11.4	15.2	23.8	28.5	28.2	107.1
Total civilian power related	(179.4)	(188.6)	(194.8)	(207.6)	(207.4)	(977.8)
Total reactor development	424.4	396.7	462.4	502.3	477.5	2,263.3
Physical research	160.9	159.6	182.8	195.7	212.6	911.6
Biological and medical research	52.9	58.2	65.1	71.0	77.1	324.3
Total AEC	2,458.0	2,419.0	2,429.0	2,423.0	2,294.9	12,023.9

Sources: Appendixes to the Budget of the United States, fiscal years 1963–66.

Note: General reactor technology, advanced systems and nuclear safety also related in part to nuclear power for defense.

TABLE VI.—FEDERAL EXPENDITURES RELATING TO CIVIL NUCLEAR POWER, FISCAL YEARS 1966–71

[In millions of dollars, actual

Program	Fiscal year— 1966	1967	1968	1969	1970	1971	Total
Reactor development:							
Civilian power reactors	89.8	102.4	121.5	125.2	124.5	129.5	692.9
Cooperative demonstration program	13.5	11.6	30.6	8.8	6.7	8.1	79.3
Euratom	3.4	2.7	2.5	1.9	—	—	10.5
General reactor technology	47.0	50.1	47.2	49.1	45.6	43.2	282.2
Advanced systems	18.1	10.4	7.6	—	—	—	36.1
Nuclear safety	21.6	28.6	32.8	33.7	37.0	34.0	187.7
Total civilian power related	(193.4)	(205.8)	(242.2)	(218.7)	(213.8)	(214.8)	(1,288.7)
Total reactor development	428.5	455.0	491.1	443.4	422.9	428.3	2,669.2
Physical research	234.4	253.4	264.7	274.0	277.8	270.7	1,575.0
Biological and medical research	82.3	85.7	88.1	88.8	89.5	88.1	522.5
Total AEC	2,140.4	2,127.8	2,184.2	2,227.4	2,178.8	2,187.3	13,045.9

Sources: Appendixes to the Budget of the United States, fiscal years 1968–72.

Note: General reactor technology, advanced system, and nuclear safety also related in part to nuclear power for defense

TABLE VII.—FEDERAL EXPENDITURES RELATING TO CIVIL NUCLEAR POWER, FISCAL YEARS 1972–74

[In millions of dollars, actual and estimated]

Program	Fiscal year 1972 actual	Fiscal year 1973 estimate	Fiscal year 1974 estimate	Total
Reactor development:				
Central station power development	163.3	176.0	184.4	523.7
Cooperative demonstration program	5.3	13.4	21.1	39.8
Nuclear safety	41.6	52.5	66.0	160.1
Technology and engineering	50.2	51.1	49.2	150.5
Total civil reactors	(260.4)	(293.0)	(320.7)	(874.2)
Naval reactors	138.9	149.8	154.2	442.9
Applied energy technology (nonnuclear)	12.5	14.2	8.0	34.7
Physical research	233.7	240.8	250.0	724.5
Controlled thermonuclear research	30.9	37.0	44.5	112.4
Biological and environmental research	88.5	93.1	98.7	280.3
Total AEC	2,256.8	2,375.8	2,539.9	7,172.5

Sources: Appendixes to the Budget of the United States, fiscal year 1974.

Note: Nuclear safety and technology and engineering may relate in part to nuclear power for defense.

U.S. ATOMIC ENERGY COMMISSION,
Washington, D.C., August 1, 1973.

Mr. WARREN H. DONNELLY,
Specialist, Science and Technology, Science Policy Research Division, Congressional Research Service, The Library of Congress.

DEAR MR. DONNELLY: We have reviewed the attachments to your letter of June 25, 1973, dealing with the cost of civilian power. We believe that combining such programs as Physical Research and Biomedical and Environmental Research with the civilian power cost in the reactor development program would be misleading. In addition, since we believe it is misleading and inappropriate to combine costs of programs such as Physical Research and Biomedical and Environmental Research and others with costs of civilian power, we have made no attempt to verify the correctness of the amounts you have identified for these programs. If future requests for amounts related to these programs develop, we would appreciate your contacting us.

Accordingly, we have prepared the attached schedule which we suggest you use in answering requests for information relative to the civilian power program. Please note that the two major components of the total cost are Base Program (which includes the civilian reactor, cooperative demonstration, and Euratom programs) and Supporting Technology.

The Supporting Technology amount represents an allocation of general reactor technology, nuclear safety and advanced systems. These allocations were based on our judgement of the application of these programs to the civilian nuclear power development. Other programs such as the Naval Reactor, and Army Reactor programs, the Rover program, and Nuclear Materials, Physical Research, and Biomedical and Environmental Research programs have also made contributions which supported the development of the civilian reactor program. However, the costs of these contributing programs cannot be accurately associated with civilian power.

If you have any questions, please let us know.

Sincerely,

JOHN P. ABBADESSA, *Controller.*

COSTS FOR CIVILIAN POWER ORIENTED ACTIVITIES—OPERATING, EQUIPMENT, AND CONSTRUCTION, THROUGH FISCAL YEAR 1972

[In millions]

	Through fiscal year 1970	Fiscal year 1971	Fiscal year 1972	Through fiscal year 1972
Base program:[1]				
Water cooled reactor	$690	$35	$34	$759
Gas cooled reactors	251	8	5	264
Liquid metal cooled reactors	531	113	167	811
Other reactor concepts	430	9	8	447
Subtotal	1,902	165	214	2,281
Supporting technology[2]	1,108	88	100	1,296
Total	[3] 3,010	253	314	3,577

[1] Includes civilian power, cooperative demonstration program and Euratom.
[2] Allocation of GRT, nuclear safety and advanced systems.
[3] Referenced on p. 776 of fiscal year 1972 Senate appropriation hearings.

DIRECT AND INDIRECT BENEFITS OF THE PRICE-ANDERSON ACT FOR COMMERCIAL NUCLEAR POWER

(By Carl E. Behrens, Analyst, Environment and Natural Resources Policy Division, November 1977)

INTRODUCTION

The Price-Anderson Act, which concerns liability and indemnification for nuclear power facilities, was enacted in 1957 with a term of 10 years. In 1965 it was extended to 1977, and in December 1975 it was substantially modified and extended to 1987.

The two basic objectives of the Act have been: (1) to remove the deterrent to early growth of commercial nuclear power presented by the risk of unlimited liability claims in the event of a catastrophic nuclear accident, and (2) to make funds quickly available to satisfy limited liability claims within an overall limit arising out of any nuclear power accident that might occur. The act in its original form stipulated that the maximum combined third-party liability for any nuclear incident should not exceed a total of $560 million. A private insurance pool was established that originally supplied $60 million of liability insurance, and the U.S. Government was authorized to provide an indemnification of $500 million, for which the nuclear power licensees paid annual fees. Since 1957, the private insurance pool has increased to $140 million, and the Government liability has correspondingly decreased.

Under the revision passed in 1975, Government indemnification has been further decreased and eventually will be eliminated as more nuclear power facilities begin operation. The Government indemnification was replaced by a system of "retroactive premiums" of $5 million for each operating power reactor. These premiums, which would be paid only in the event of an accident exceeding in liability the $140 million coverage by private insurance pool, would be the responsibility of the reactor owners. There are at present (October 1977) 67 reactors with operating licenses, representing $335 million in retroactive premiums; added to $140 million in the private pool, private insurance provides $475 million. Government indemnity is reduced to $85 million, bringing the total to the $560 million limit. The Price-Anderson Act as amended provides that as more reactors begin operation, the Government indemnity will be eliminated, and the limit on liability will increase from the present $560 million to the amount of the total of the private insurance pool and the retroactive premiums.

Benefits from the Price-Anderson limitation of liability

The benefit accruing to the nuclear industry from the liability limitation cannot by directly quantified, since no accidents have yet occurred that approach that limit. (In fact, no claim has yet been filed against the private nuclear insurance pool or against the Government under the Price-Anderson Act attributable to a nuclear accident at a commercial nuclear reactor.) Thus, during the developmental period of nuclear power, the limitation cost nothing.

Nevertheless, it is generally agreed that the commercial development of nuclear energy would not have taken place without some form of liability limitation such as was provided by the Price-Anderson Act. Similar limitations, some much lower than the Price-Anderson figure of $560 million, were adopted in other countries where nuclear power was developed. The refusal of private industry to enter into commercial nuclear power without a liability limitation arose because the probability of a catastrophic accident was not known; nor could such a probability be calculated in the absence of operating experience with nuclear power reactors, which are substantially larger than the small naval and test reactors that had been operating for some years. The alternative to private generation of nuclear power would have been Government construction and operation of power reactors until such time as the risks and probabilities of serious accidents could be estimated. This path was unacceptable to the Eisenhower Administration, which emphasized rapid private development of nuclear power.

Because of the importance of the liability limitation in the development of nuclear power, it is clear that this feature of the Act was of substantial benefit to the industry. The monetary risk involved was, and remains, largely a responsibility of the Government. In passing the Price-Anderson Act, the Congress recognized its responsibility to take action in the event of an accident that exceeded in damage the $560 liability limitation, and in the 1975 revision this responsibility was explicitly stated in the language of the legislation itself.

Some indication of the significance of that risk can be gained from estimating the likelihood of a nuclear accident that caused liabilities in excess of the $560 million. A 1957 study by the Atomic Energy Commission's Brookhaven National Laboratory, using deliberately extreme assumptions, indicated that a "highly improbable" accident could result in damages considerably greater than $560 million.[2] The report estimated that the likelihood of accidents "which would release major amounts of fission products outside the containment"—the kind of accident that would cause large amounts of damage and injury to the general

---

[2] U.S. Atomic Energy Commission. Theoretical Possibilities and Consequences of Major Accidents in Large Nuclear Power Plants; A Study of Possible Consequences if Certain Assumed Accidents, Theoretically Possible but Highly Improbable, Were to Occur in Large Nuclear Power Plants. [Washington] U.S. Atomic Energy Commission, 1957.

public—ranged from "one chance in 100,000 to one in a billion per year for each reactor." But the author of the report emphasized that these estimates were highly subjective. The numbers, they said, "have no demonstrable basis in fact and have no validity of application beyond a reflection of the degree of [the authors'] confidence in the low likelihood of occurrence of such reactor accidents."

By the early 1970's, enough design and operation experience had been accrued to make a more precise estimate of probabilities possible. The Reactor Safety Study, begun by the Atomic Energy Commission and finished by the Nuclear Regulatory Commission, was issued in final form in 1975.[3] It examined the consequences of a variety of possible accidents in nuclear reactors of the kind currently being built, and computed the probability of such accidents occurring. It concluded that, with 100 power reactors operating, the chance of an accident causing 10 or more fatalities was about one in 30,000 per year. In terms of property damage, the probability of an accident among 100 operating reactors causing damage over the $560 million limitation was computed to be about one in 2,000 per year. The worst accident predicted by the study, involving 3,300 fatalities and property damage of about $14 billion, was computed to have a probability of one in 10 million with 100 power reactors operating.

The Reactor Safety Study has been subject to some challenge, both on methodological grounds and on the details of its conclusions. However, its general results have been widely accepted, along with its conclusion that the probability of an accident exceeding the $560 million limitation is extremely small.

While the importance of the liability limitation during the development of nuclear power is clear, there is some debate whether continuation of the limitation is necessary for further expansion of the industry. A Federal judge, in declaring the limitation unconstitutional, concluded that "but for the limitation of the Price-Anderson Act, the nuclear power plants would not be built . . ." [4] Most testimony by industry spokesmen during consideration of the 1975 extension of the Act, however, indicated that absence of the liability limitation would cause financial and technical difficulties, but would not halt construction of nuclear power facilities. Thus the limitation remains of some benefit to the industry, although the amount of the benefit is not quantifiable.

Benefits from Government indemnification

Unlike the case of the limitation on liability, it is possible to estimate the monetary benefit which accrued to the industry because of the Government indemnification of liability beyond commercial coverage but within the $560 million limitation.

Government indemnification of nuclear plant liability was necessary during the years of development of the technology because private insurance was not available to the limit of liability set by the Price-Anderson Act. The private insurance pool started in 1957 at $60 million, and at present is $140 million. Before the "retroactive premium" system went into effect in August 1977, Government indemnification covered the remaining $420 million. If liability insurance were available in that amount, it would be much more expensive than the Government fees that the utilities actually pay, which amount to about $90,000 per power reactor per year. The difference between the premiums that would be necessary to buy the additional $420 million and the fee paid the Government is considered by some, but not all, analysts to represent a subsidy, although the actual cost to the Government has been nothing, since no major accidents have occurred. In fact, by August 1977 the Government had collected approximately $10 million in fees. No claims have ever been made against the Government for indemnity liability.

In 1975 the General Accounting Office estimated the value of the Government indemnity by calculating the additional cost of private liability insurance if it were available, and subtracting the Government fee.[5] Since private insurance premiums are less when more than one reactor is located at a single site, the GAO computed two figures. For a single reactor, additional liability would cost $235,480

---

[3] U.S. Nuclear Regulatory Commission. Reactor Safety Study: An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants. [Washington] U.S. Nuclear Regulatory Commission, October, 1975, p. 3 "Wash-1400 (NUREG-75/014)".

[4] *Carolina Environmental Study Group* v. *U.S. Atomic Energy Commission*. U.S. District Court W.D. North Carolina, Charlotte Division, March 31, 1977. 431 F. Supp. 226 (1977). The U.S. Supreme Court has agreed to review the ruling. (Court Will Review Ruling on A-Mishap Liability Limit. Washington Post. Nov. 8, 1977, p. A7.)

[5] Comptroller General of the United States. Selected Aspects of Nuclear Powerplant Reliability and Economics. Washington, Aug. 15, 1975. Appendix I. p. 18–19.

per year, less the $90,000 fee, leaving a subsidy of $145,000. For two reactors, the additional liability would cost $294,000, less $180,000 in fees, for a subsidy of $114,350, or $57,175 per reactor.

The GAO figures were computed when the private insurance pool was $125 million, instead of its present $140 million, and the Government indemnity was $435 million. A rough estimate of the cumulative subsidy of the Government indemnification through 1977 can be made by using GAO's figures. If half the reactors built were on single-unit sites and the other half on multi-unit sites, then the average additional premium would be approximately $190,000. The ratio of this premium to the actual Government fee, $90,000 is 2.1. Multiplying that ratio by the $10 million paid in Government fees would yield a total cumulative premium of $21 million, or $11 million in subsidy.

Since the 1975 revision of the Price-Anderson Act, with its provision of "retroactive premiums" to be paid by utilities in case of an accident, the Government indemnity is expected to be eliminated within the next several years.

Federal Subsidy for the U.S. Nuclear Industry: A Conceptual Discussion

(By Warren H. Donnelly, Ph.D., Senior Specialist, Energy Environment and Natural Resources Policy Division, February 3, 1977)

A CONCEPTUAL DISCUSSION OF FEDERAL SUBSIDY FOR THE U.S. NUCLEAR INDUSTRY

Purpose

One criticism of Federal programs for nuclear energy is that they provide a subsidy for the U.S. nuclear industry which has, by inference, enabled it to produce and sell nuclear power reactors sooner and at lower costs than would have been the case without subsidy, and that operating costs of these reactors also are less by reason of such subsidy. This, critics say, gives nuclear power an unfair competitive advantage over other new sources of energy such as solar power, ocean energy or geothermal energy, and has discouraged their development and application.

Discussing the question of Federal subsidy to the U.S. nuclear industry is a subjective matter, for so much depends upon assumptions about what constitutes a subsidy, assumptions that vary widely among economic and political observers and leaders. One man's unwarranted subsidy is another man's wise investment in the public interest.[1]

The purpose of this memorandum is to outline in concept the principal elements of what some observers might consider to be Federal subsidy too the U.S. nuclear industry. It should be kept in mind that other observers will not agree that all of these elements are subsidies, or that if they are, they are unwarranted.

A background note

Under President Eisenhower's Administration, Congress revised the Atomic Energy Act of 1946 to open the way for commercial nuclear power in the United States. Lewis L. Strauss, then chairman of the Atomic Energy Commission, strongly advocated the creation of a wholly private nuclear industry capable of supplying all of the materials, equipment, services and installations needed to generate nuclear power. This vision has not been accomplished, for in 1977 the U.S. nuclear industry still depends upon the Federal Government for uranium enrichment services, and there is some speculation that the Federal Government may also be called upon to provide long-term storage of used nuclear fuels, reprocessing of such fuels and long-term management of radioactive wastes from such reprocessing. However, the costs of these services are and would in principle be paid for by the industrial users. An issue might be whether the charges for these services recover all costs or include a subsidy.

Part of the issue of Federal subsidy for nuclear power is an extension of the issue of subsidy to generation of electricity. Some parts of the U.S. society view direct Federal energy operations, such as TVA, as a desirable function of the Government. Others oppose them not only as inconsistent with U.S. traditions of private enterprise but also as incorporating subsidies that prevent private competition.

[1] Webster defines subsidy as (a) a grant of money from one government to another, especially to aid in carrying on a war against a third; (b) a government grant to a private enterprise considered of benefit to the public: (c) in England, formerly, money granted by Parliament to the king. Webster's New World Dictionary of the American Language, 1966.

Such elements of subsidy are said to include interest rates on capital investments lower than paid by private enterprise, no requirement to make a profit, and no requirements to pay certain State or local taxes, or to charge all of the costs of private business. These elements of subsidy would be the same whether an undertaking generated electricity from water, conventional fuels or uranium, and would apply to generation of nuclear power by agencies such as TVA, or the New York State Power Authority. They would also apply to government ownership and operation of supporting industrial facilities for nuclear energy including those for enrichment, fuel reprocessing, fuel storage and waste management.

Elements unique to nuclear power

Depending upon how one defines and views subsidy, the following may be considered to be elements of Federal subsidy to the U.S. nuclear industry:

Experience gained from AEC contracts for military applications of nuclear energy.—Leading U.S. companies in the nuclear industry have had many contracts with the Atomic Energy Commission for development of nuclear power for military purposes. Through these contracts, the companies have acquired a cadre of tested, experienced engineers and scientists, some of whom they have transferred to civil nuclear work after these personnel gained their experience at government expense. This advantage is not usually available to other companies that would enter the nuclear field, and is not available for companies that would enter into development and marketing of new energy technologies such as solar, wind, geothermal, or ocean heat energy, Note that other high-technology industries such as communications and electronics also benefited greatly from military contract experiences.

Indemnification for nuclear liability.—A controversial Federal service to the U.S. nuclear industry, which some critics protest as a subsidy, is the indemnification and limitation of liability provided by the Price-Anderson amendments to the Atomic Energy Act of 1954. Utilities operating nuclear power plants have to carry commercial insurance to provide protection to the public equal to the maximum amount of nuclear liability insurance available (currently $125 million) from private insurance pools. Government indemnity, for which the utilities pay a small fee, now provides coverage up to a limit of $560 million, a ceiling which some analysts view as inadequate. While no major claims have been paid out, some analysts argue nonetheless that should a catastrophic accident occur with a nuclear power plant, the government indemnification would constitute a subsidy, as would the cutoff of liability above the total of $560 million.

The most recent amendment of the Price-Anderson provisions of the Atomic Energy Act provides for a gradual phasing out of the Federal indemnity. As extended, the law calls for continuation of two layers of private insurance—a primary layer provided by the private insurance pools and a second layer in the form of premiums that would be assessed across the entire nuclear generating industry following a major nuclear accident. In the event of an accident that creates liability above commercial insurance limits, the utilities would pay up to $5 million for each nuclear power plant they are licensed to operate. Government indemnity will remain in effect until the two layers of private insurance reach the limit of $560 million. At that time, the limit on liability will be adjusted upwards annually by an amount equal to the number of new plants licensed that year multiplied by the $5 million deferred premium on each plant. This amendment to NRC regulations was published in the Federal Register on January 3, 1977, to take effect on August 1, 1977.

Assistance to the uranium industry.—In the 1950s the AEC provided bonuses, technical services and other incentives to create a U.S. uranium mining and milling industry. While the uranium thus produced went to the manufacture of nuclear weapons, the costs of these incentives definitely helped to create the domestic industry to supply fuel for civil nuclear power.

More recently, the Congress appropriated funds to help pay the costs of removing and replacing backfill from certain buildings in uranium mining States that contained radium and that had been taken from tailing piles of abandoned uranium mills. These appropriations could be regarded as a form of subsidy because they pay expenses not paid by the original buyers of the mills. There is still the outstanding question of who will pay the costs of stabilizing large tailing piles at abandoned uranium mills which are causing local pollution by wind and water erosion of materials containing radium. If these costs are funded in part or in whole by the Federal Government, some analysts would argue that this too would constitute a subsidy to the U.S. nuclear industry.

Government funding of research and development for civil nuclear power.—Large scale Federal funding of research and development to create the technologies of nuclear power has been characteristic of the U.S. nuclear industry. Some of this work is done in Government-owned, privately operated laboratories. Much of it is done in the laboratories of private establishments in the U.S. nuclear industry which not only benefits the industry as a whole, but provides particular benefit to the company doing the work. For the 27 fiscal years 1948–1974, I have estimated that the total was $8.2 billion, of which $3.7 billion was for civil power. During this same period, the AEC funded about $3.9 billion in physical research and $1.5 billion for biological, medical and environmental research. Much of this research was of benefit to the civil nuclear industry. Details of this estimate appear in my paper of June 22, 1973, enclosed.

ERDA funding of research and development for nuclear power continues and the Nuclear Regulatory Commission now is also funding research and development which undoubtedly will be of some benefit to the U.S. nuclear industry. As shown in Tables I and II, ERDA programs relating to civil power have a budget request of $3.1 billion for fiscal year 1978. Some analysts would argue that these funds should come from private sources and therefore constitute a subsidy.

TABLE I.—FUNDING OF ERDA PROGRAMS DIRECTLY RELATING TO CIVIL NUCLEAR POWER

[In millions]

Program	1976 actual	TQ actual	1977 estimate	1978 estimate
Fusion power R. & D.:				
(a) Magnetic fusion	$115	$41	$170	$203
(b) Laser fusion	57	18	76	91
Fuel cycle R. & D	43	24	142	264
Liquid metal fast breeder reactor	304	92	462	578
Nuclear research and applications	122	39	148	171
Nuclear Regulatory Commission safety facilities			21	22
Total	641	214	1,019	1,329

TABLE II.—FUNDING OF ERDA PROGRAMS INDIRECTLY RELATING TO CIVIL NUCLEAR POWER

[In millions]

Program	1976 actual	TQ actual	1977 estimate	1978 estimate
Environmental R. & D	$125	$41	$150	$173
Life sciences research and biomedical applications	37	11	41	37
High-energy physics	146	39	165	185
Nuclear physics	52	15	60	66
Basic energy sciences	108	32	121	138
Nuclear materials security and safeguards	10	4	24	33
Naval reactor development	186	53	203	220
Nuclear explosives applications			1	1
Uranium enrichment	644	193	878	1,005
Total	1,308	388	1,643	1,858

Particularly controversial items in the ERDA budget request are $239 million for plant and capital equipment for the liquid metal fast breeder reactor and $824 million for uranium enrichment. These amounts are in addition to those of Tables I and II.

Other earlier AEC projects supportive of the civil nuclear power industry include construction and operation of the Shippingport Light Water Reactor, the AEC's power demonstration reactor program, and the AEC's collaborative research and development with EURATOM.

Uranium enrichment.—Under authority of the Atomic Energy Act of 1954, as amended, ERDA provides uranium enrichment services for domestic and foreign customers. The enrichment charge is supposed to recover costs to the Government. However, it is not clear what capital value is assigned to the enrichment facilities (original book value or replacement cost), and what charges are made for invested Government capital in calculating the enrichment fees. President Ford in his final message on the Nation's energy problems,[2] mentioned the need for legislation

[2] The Nation's Energy Problems. Message from the President of the United States. January 10, 1977. H. Doc. No. 95–33, p. 12.

to authorize an increase in the price for enrichment services "to assure a fair return to the taxpayer for their investment, to price services more nearly comparable to their private sector value, and to end unjustified subsidy by taxpayers to both foreign and domestic customers." His statement strongly implies the existence of what his administration considered to be a subsidy. On the other hand, the present enrichment facilities were built to supply uranium for the weapons program, so the capital costs would have been incurred regardless of whether or not the nuclear industry existed.

Spent fuel storage.—The decision of the Nuclear Regulatory Commission to reexamine the licensing of plutonium in light water reactors (plutonium recycle) and President Ford's strong statement of October 28, 1976, against reprocessing of nuclear fuels in the near future are creating a probable shortage of facilities for storage of used nuclear fuel. At the moment there seems little prospect that private investors will finance construction and operation of the needed facilities, so there is the likelihood of proposals to and pressures on the Federal Government to establish such facilities. If this is done, there could be an element of subsidy in charges made for use of such facilities, depending upon how the charges are calculated, and to what extent these calculations include normal costs and profits of private business.

Spent fuel reprocessing.—Although reprocessing of nuclear fuels is being discouraged in the United States, reprocessing will become necessary in later years if the breeder reactor comes into use. In the meantime, a large privately financed reprocessing plant is nearing completion in South Carolina. The backers of this plant, however, are seeking about $300 million in Federal assistance to provide additional features required by changes in regulations of the Nuclear Regulatory Commission. There are also some proposals that the plant, or part of it, should be used by the United States as part of an international venture in reprocessing. In any event, some analysts will consider Federal assistance to this plant as a form of subsidy to the U.S. nuclear industry.

Radioactive waste management.—The ultimate perpetual storage of intensely radioactive wastes from nuclear fuels remains a missing part of the nuclear fuel cycle. No private facilities exist or are contemplated for management of high-level wastes after they leave the reprocessing plant. While pressure for an immediate solution to management of such wastes from civil nuclear power has been reduced by the present holding action on nuclear fuel reprocessing, ERDA is continuing to fund development of methods for commercial waste. An example of circumstances that can generate pressure for direct Federal involvement in high-level waste management is the case of the Nuclear Fuel Services fuel reprocessing plant near Buffalo, New York. The company has gone out of business, in part because of changes in Government regulations. At its abandoned facility are quantities of liquid, high-level radioactive wastes. Under NRC regulations, these must be solidified and transported to a permanent waste management center. At the moment, New York State is responsible for the safekeeping of these wastes and has approached ERDA for financial assistance to construct a temporary facility to solidify the wastes, assuming there is a place where they subsequently could be sent—although there is no such place now. The costs could be many millions of dollars. If Federal funds are provided, some analysts are likely to consider them a Federal subsidy to pay for costs that should have been charged to those who sent fuel to NFS for reprocessing. To complicate matters, some of the reprocessed fuel came from the AEC weapons program.

Also, at some time during the next few years, particularly if the NRC and the Administration ultimately decide to proceed with plutonium recycle, there are likely to be proposals that the Federal Government establish and operate permanent waste management facilities and charge for their services. Here too, the calculation of Government charges might be criticized as including subsidy if all costs of a comparable private venture were not included. Complicating this situation is the long-term management of similar wastes from the production of nuclear weapons. The volume of these weapons-derived wastes is expected to exceed by a factor of 10 or more the volume of wastes produced by the year 2000 from reprocessing of civil nuclear fuels. Since much of the weapons-derived wastes are stored in inadequate facilities, sooner or later the Federal Government will have to establish a permanent management center.

Financial assistance to U.S. nuclear exports.—The U.S. nuclear industry has been a strong competitor in the world market for nuclear power. One strength of the U.S. nuclear industry has been financial assistance from the Export Import

Bank. Every sizable nuclear power reactor exported from the United States, except for the Tarapur reactors to India, has had some form of Export Import Bank assistance. Tarapur was financed through AID with a two percent loan. Any financial difference between Export Import Bank assistance and that obtainable from private sources could be regarded by some analysts as a form of Federal subsidy.

Costs of regulating nuclear energy.—Some analysts propose that industries should pay the costs of regulation. From this point of view, any difference between annual costs of regulation and income to the Federal Government from license fees or other fees or taxes for regulation can be considered as a subsidy. The Nuclear Regulatory Commission has requested budget authority of $292 million for fiscal year 1978 to cover costs of nuclear regulation, inspection and enforcement, development of standards, safeguards, and research. While the NRC does charge for processing of licenses for nuclear power plants, the income from these licenses is very small compared with the budget request.

A History of Uranium Prices and Government Enrichment Policy

(By Russell J. Profozich, Analyst in Energy and Utilities, Economics, Division, April 18, 1979)

This report presents historical information on prices of U.S. uranium production and on U.S. Government uranium enrichment services. Both as a major purchaser of uranium and as the only domestic supplier of uranium enrichment service, the U.S. Government, through its various programs and policies, has had a major impact upon the uranium industry.

INTRODUCTION

The purpose of this report is to present historical and background information on the prices of U.S. uranium production and on U.S. Government uranium enrichment services. Information contained in this report is intended to increase the awareness of the reader of historical price trends within the uranium industry and the effect of Government policy on those trends. Although an exact cause and effect relationship between Government policy and uranium pricing cannot be determined, and is not attempted here, there can be no doubt that various Government policies and programs have had a significant impact on the price of uranium both in the U.S. and abroad.

The first section of this report presents information on historical price trends for uranium in the United States from the time of development of the uranium industry in the early 1940's until mid-1978. Although the information presented in this section concentrates on U.S. production, information is also presented on non-U.S. production and pricing of uranium.

The second section of this report contains historical information regarding the availability and pricing of uranium enrichment services both domestically and from foreign sources. The information contained in the first and second section is taken largely from two reports which were prepared for the use of the Congressional Research Service by the Nuclear Assurance Corporation. These reports are entitled "The History and Trends of U_3O_8 Prices" and "The History of Enrichment Prices."

The third section of this report shows a calculation of U.S. Department of Energy (DOE) enrichment prices for 1976 both under DOE electric power procurement contracts and assuming the use of imported fuel oil in the generation of electric power supplied to the Government enrichment facilities. This section is intended to show the effect of energy prices on the cost of enrichment services supplied by the Federal Government.

The fourth section presents a brief summary and conclusions.

HISTORICAL PRICE TRENDS FOR URANIUM IN THE UNITED STATES [1]

The uranium industry in the United States developed in the early 1940's for the purpose of supplying uranium for the United States and United Kingdom weapons programs. Both countries, at that time, were almost totally dependent on foreign sources of supply to meet their uranium requirements. Prior to 1948, the

[1] Warren H. Donnelly, Senior Specialist, Energy, and Richard A. Nelson, Analyst in Energy Economics' assisted in the preparation of this report.

U.S. Atomic Energy Commission (AEC) had purchased 10,156 tons (short ton= 2000 lbs.) of uranium (U_3O_8) from foreign sources and 1,435 tons from domestic producers. In 1947, the available U.S. reserves of U_3O_8 were estimated to be only 2,000 tons.

As a stimulus to domestic production, the AEC established guaranteed price levels for uranium ore and for U_3O_8 and provided bonuses for initial production from new mines. Natural uranium ore consists of several isotopes including U^{238}, U^{235} and U^{234}. Only U^{235} is fissionable and therefore useful in generating power. After mining, uranium ore is milled and converted into a uranium concentrate called yellowcake (U_3O_8). It is this yellowcake which is the input to the enrichment process (to be described below) eventually providing fuel for nuclear reactors.

As a result of the Government programs, U.S. production of U_3O_8 increased to 824 tons in 1952, and uranium reserves increased to approximately 10,000 tons U_3O_8 in that year. During the 1952 to 1958 period, private exploration for uranium ore in the U.S. increased dramatically. Aided by new sophisticated scientific exploration methods, large ore deposits were discovered. The AEC estimated that a total of 261,000 minable tons of contained U_3O_8 were discovered during this seven-year peiod. By 1960, twenty-three privately-owned uranium mills located in the western U.S. with a combined capacity of approximately 23,000 tons of ore per day were in operation. Uranium ore was produced by 317 mines in 1948, by 1,323 mines in 1956, 1017 in 1960, 609 in 1966 and 368 in 1967. Approximately 85 percent of total U.S. production during this period, however, came from 10 percent of the mines.

The rapid buildup in domestic uranium exploration and production during the period 1952 to 1958, can largely be credited to guaranteed markets and incentive pricing by the AEC. For the calendar years 1948–1957, the AEC paid an average price of \$10.83 per pound for U.S. produced U_3O_8. During the 1958–1966 period, an average price of \$8.36 per pound was paid. The average annual purchase price per pound of U_3O_8 decreased from a high of \$12.43 in 1958 to \$7.82 in 1963, \$8 per pound during 1964–1966, and a low of \$5.56 per pound in 1970.

In 1958, the AEC announced that it would limit its new purchase commitments of U_3O_8 to production from U.S. ore reserves developed prior to November 24, 1958. Following this action, exploration for new ore reserves declined rapidly as existing reserves were used to meet scheduled deliveries and new exploration was deferred until new markets developed.

In November 1962, the AEC issued an invitation to companies which had contracts with the AEC to defer deliveries of U_3O_8 in exchange for an additional contract commitment. The purpose of the invitation was to provide some market for producers until a commercial market developed. The program provided for a voluntary deferral of delivery until 1967 and 1968 of a portion of the U_3O_8 previously scheduled for delivery prior to 1967. In return, the AEC offered to purchase additional quantities of U_3O_8 in 1969 and 1970 equal to the amount of the deferrals. Eleven uranium mills having approximately 70 percent of peak capacity elected to participate in the program.

In 1967 and 1968, the AEC paid \$8/lb for U_3O_8. The uranium delivered in 1969 and 1970 under the voluntary extension program was to be purchased at a fixed price determined for each producer at 85 percent of the average production cost per pound for the period 1963–1968, plus \$1.60, subject to a maximum price of \$6.70/lb. An average price of \$5.50 to \$6.00 per pound for U_3O_8 was paid for deliveries under the extension program. These lower prices were unexpected by the industry, since the AEC had "pegged" the price of U_3O_8 in 1956 at \$8/lb. This lower price put pressure on marginal producers operating at low capacity levels and acted to discourage new investment in the industry.

Since the U.S. AEC was the dominant world purchaser of U_3O_8 prior to 1964, the pattern of production outside the U.S. was similar to that of domestic production. During the period when the AEC was encouraging domestic production by offering relatively high prices, foreign producers in Canada, South Africa and the Belgian Congo also expanded production. When the AEC began to cut back on its purchases of U_3O_8, non-U.S. production declined. The Energy Research and Development Administration (ERDA, one of the successor agencies to AEC) will not disclose the prices paid to foreign producers however, it is estimated that those prices were very similar to those paid to U.S. producers.

A. Development of a commercial market

On August 26, 1964, the Private Ownership of Nuclear Materials Act was passed as an amendment to the Atomic Energy Act of 1954. This Act gave private

industry the right, for the first time, to own enriched uranium used to power nuclear reactors. Most utilities and other customers, however, continued to lease enriched uranium from the AEC until toll enrichment services were offered by the AEC for privately supplied uranium beginning on January 1, 1969. After December 21, 1970, the AEC was prohibited from entering into new leasing arrangements and all existing leases were terminated by July 1, 1973.

As a further stimulus to the U.S. uranium industry, the Nuclear Materials Act of 1964 was passed. This Act prohibited the AEC from toll enriching foreign source uranium intended for domestic use until the domestic uranium industry could become well established. This Act gave customers the alternative of leasing enriched uranium from the AEC or purchasing it. This provision also affected non-U.S. producers and created a two-tier market, with prices of non-U.S. uranium generally lower than those of domestic production.

The period of 1966–1973 was a transition period for the uranium industry with the market evolving from a governmental market to a commercial market. The uranium industry was rapidly consolidating during this period to bring production capacity more in line with the lower levels of AEC purchases. The overcapacity situation resulted in producers competing for the small developing commercial market through incremental pricing and distress period strategies. Overall, however, the industry began to expand in order to meet the expected future commercial demand for uranium.

A "buyers market" existed in the uranium industry during this time period. The industry could be characterized as having a diversity of suppliers (including mining companies, oil companies and uranium companies), adequate capacity to meet near and intermediate term requirements, relatively stable prices and brisk competition among suppliers. Domestic uranium production declined from a peak of 17,600 short tons of U_3O_8 in 1960 to about 10,000 short tons of U_3O_3 per year in the mid 1960s. The requirements of commercial powerplants were only around 4,000 to 5,000 short tons per year; however, producers expected an upturn in commercial requirements in the 1970s due to the start-up nuclear plants ordered in 1965 and 1966.

During this period, most utility companies argued for removal of the AEC embargo on uranium imports in order to further stimulate competition among suppliers. Non-U.S. producers also argued for removal of the embargo. These producers felt that they were being treated unfairly since the AEC had first encouraged development of uranium production during its procurement program and then had shut off the U.S. market entirely to foreign producers. Largely due to the overcapacity situation of the industry, a uranium producers' "club" was formed among non-U.S. producers and governments.

The first meeting of the "club" took place between government and industry representatives of the major producing countries in Paris on February 2–4, 1972. The original members of the "club" were reported to include:

Company and Country:

- Denison Mines, Ltd., Canada;
- Rio Algom Mines, Ltd., Canada;
- Nuclear Fuels Corporation of South Africa, Ltd. (Nufcor); South Africa;
- Mary Kathleen Uranium, Ltd., Australia;
- Peko Wallsend, Ltd., Australia;
- Electrolytic Zinc Industries, Ltd., Australia;
- Queensland Mines, Ltd., Australia;
- Rio Tinto Zinc Corp., Great Britain; and
- Uranex, France.

The purpose of the first meeting was reported to be to discuss possible price stabilization methods to ensure an adequate price for uranium. However, because of the current and projected future oversupply situation of the industry, there was little progress toward the formation of any cartel-like arrangement. A second meeting was held in Paris on March 13 and 14, 1972 of representatives from Australia, Canada, France and South Africa again with little progress toward an accord reported. Nevertheless, in June 1972 it was reported that the "club" had established a cartel-like marketing arrangement which established a floor price for U_3O_8 at about $6/lb for 1972, increasing to $8/lb in 1978. Suppliers in participating countries would refuse to quote prices for material to be delivered after 1980. A formal organization was established by the summer of 1972. Based in Paris, it was initially called the Uranium Marketing Research Organization (UMRO).

B. The transition to a seller's market

By 1970, the AEC had accumulated an inventory of approximately 100,000 short tons of U_3O_8 and was considering disposing of this inventory on the open market in direct competition with uranium producers. The AEC was also reviewing its embargo policy which the uranium industry feared would threaten to open the U.S. market to foriegn producers. In addition, commercial nuclear reactor projects were being delayed due to licensing problems, causing requirements for U_3O_8 to slip and utility inventories to build up. All of these factors acted to keep prices down and discourage investment in exploration and new production capacity. By 1973, a potential domestic supply shortage had developed.

In late 1973, several unrelated events took place which increased the demand for domestic uranium and caused a transition in the industry from a buyer's to a seller's market. First of all, the AEC changed its method of contracting for enrichment services from the previous requirements type contract to the Long-Term Fixed Commitment (LTFC) Contract. This type of contract, unlike its predecessor, required customers firmly to commit to exact quantities of separtive work (enrichment services) to be provided each year for a rolling ten-year period, agreed to eight years in advance of reactor operation. Costly penalties were included in the contract for inability of customers to provide feed uranium according to the contract schedule. As a result of the new AEC policy, utilities began to secure ten- to twenty-year forward commitments of uranium from suppliers.

Secondly, the Arab oil enbargo in the fall of 1973 had a dramtic affect on the nuclear industry. The increased cost of oil was expected to induce a major increase in demand for nuclear power. Uranium export policies were revised by governments of some supply countries and the price of uranium began to rise to levels competitive with those of fossil fuels.

Other factors influencing the uranium market at this time included the election of a Labor Government in Australia which halted the development and marketing of the large, low-cost Australian reserves; while, the increased world price of gold led to the processing of lower grade ore in the mines of South Africa. Uranium is produced as a by-product of the gold mining operation. Since the uranium grade in the ore is proportional to the grade of gold, a lower level of uranium production resulted. In addition, the increase rate of inflation and more stringent mining health and safety regulations caused producer's costs to increase and/or productivity to decline, with the result that full escalation provisions became a common provision in supplier contracts.

Worldwide nuclear reactor orders also were at record levels during 1973, U.S. utilities commited for 44 units during 1973, totaling 46,000 Megawatts (MW) of nuclear generating capacity. Because of the over-capacity situation of the industry and the possible lifting of the Government-imposed embargo on foreign imports, U.S. producers committed a major share of their production capacity by the end of 1973. A total of 52,000 short tons of U_3O_8 was committed in 1973 at a base price in most cases of less than $10/lb.

At the beginning of 1974, many utilities still had major uncommitted uranium requirements for the immediate and long-term future. At this time the Tennessee Valley Authority (TVA) announced that it would solicit proposals to fulfill its long-term uranium requirements. During 1973, TVA requested bids on up to 86 million pounds of uranium for delivery in 1979 to 1990. Only three bids were received and all were rejected, but the mere presence of TVA in the market for an amount of U_3O_8 which could tie up all existing uncommitted production capacity had a dramatic effect on the market. Producers began to reverse the traditional method of bidding for sales and asked interested buyers to make offers on available production.

The first announced uranium purchase in 1974 was made in January by Pennsylvania Power and Light. The transaction involved the purchase of 6,400,000 pounds of U_3O_8 for delivery beginning in 1978. The reported value of the contract was $100 million, or about $15.60/lb. This compares with the average unescalated price of $7.50/lb. for 1973 purchases for delivery in 1978. By late 1974, several major U.S. producers had sold most or all of their known reserves and assured production capacity through the early 1980s and had withdrawn from the market. With most current capacity already committed, any additional commitments would have to be priced high enough to justify investment in new mining and milling facilities. At the same time, major non-U.S. producers were becoming increasingly affected by governmental policies. The Canadian Government announced a new uranium policy on September 5, 1974, which gave priority to its own domestic users for available supplies of Canadian-produced uranium.

Faced with uncertainties in price and availability of supply, serveral utilities employed new methods of ensuring an adequate supply of uranium. In the early 1970s, TVA entered into arrangements with American Nuclear Corp. which allowed TVA to gain an interest in American Nuclear's uranium by providing funds to the company for exploration and development of its properties. In 1973, TVA expanded its arrangement with American Nuclear by leasing uranium mineral rights from Federal-American Partners (owned jointly by Federal Resources, 60 percent, and American Nuclear, 40 percent), and gaining first call on use of the Partners' milling facilities. In 1974, Commonwealth Edison Co. acquired the Cotter Corporation milling facility and land rights. Other utilities, both foreign and domestic, entered into similar arrangements with suppliers as available supplies tightened.

As a result of the tight market and rising prices, exploration drilling increased. Also, in 1974 Reserve Oil and Sohio announced plans to build a new mine-mill complex for completion in 1976. This was the first new mill project to be built since 1972. Some relief in the tight supply situation developed in late 1974 as a result of the large number of U.S. reactor delays and cancellations which occurred at this time. These delays and cancellations, howerver, did not greatly relieve the tight supply situation due to the LTFC contracts required by the AEC.

The subsequent combination of numerous reactor delays, AEC long-term fixed commitment contracts, and long-term supply contracts between utilities and producers, caused utility company inventories of uranium to accumulate. Despite this accumulation of inventories, there were still reactor requirements that were not covered by supply contracts. The utilities which owned these reactors found themselves in a bidding war for the remaining uncommitted production capacity, with the result that small quantities of available material were exerting a large impact on market price.

Another factor contributing to the uranium supply problem was the lack of reprocessing capacity (i.e., recycling waste material and spent fuel to be used as future uranium supply). Reprocessing plants throughout the U.S. and the rest of the world were being delayed or cancelled. Thus, the fuel cycle was showing the first signs of remaining unclosed for the forseeable future. While these events did not have an immediate effect on uranium supplies, they did affect the industry's perception of future uranium availability.

In mid-1974, United Nuclear negotiated a sale with an undisclosed buyer for delivery in 1976–78 at an estimated non-escalation price of \$13.50/lb. In September, 1974, Duke Power Co. sold 2 million pounds of U_3O_8 out of inventory to Westinghouse at a price of about \$13/lb. Duke Power's sale was necessitated by an immediate cash flow problem. During the latter part of 1974 other utility companies sold parts of their inventories for the same reason. Many purchasers of this material were non-U.S. utilities who were in the U.S. market because of a lack of availability of supply elsewhere. In 1974, the spot price of U_3O_8 increased from about \$7/lb. at the beginning of the year to around \$15/lb. in December.

At the beginning of 1975, virtually all available supplies of uranium had been committed to contract. Producers, then, began to expect buyers to share the risk and cost of exploration and development of new production facilities. Prices continued to increase and non-U.S. buyers remained active in the U.S. market. Washington Public Power Supply System (WPPSS) purchased 1 million pounds of U_3O_8 from Rio Algom of Canada in May 1975 for delivery in late 1975 or early 1976 at a price of \$22/lb. This purchase was significant in that it established for the first time a spot market price for U_3O_8 in excess of \$20/lb. By summer 1975 the spot price reached \$25/lb., and in October sales were made at \$26/lb. The rise in price abated somewhat toward the end of the year, due mainly to ERDA's "open season," on enrichment which allowed enrichment customers to reschedule enrichment services to more closely match their requirements.

A major disruption of the uranium market occurred in July 1975, when Westinghouse Electric Corp. announced that it was reviewing its legal obligation to supply uranium to its customers. In September, Westinghouse announced that it considered itself excused from its contractual obligations to supply over 60 million pounds of U_3O_8 to its customers under provisions of Section 2–615 of the Uniform Commercial Code (UCC). Westinghouse proposed, in accordance with the UCC provisions, to allocate its existing supply of uranium equally among its customers, giving each customer 18.25 percent of the contracted amount of uranium. This reduction in available supply left several utilities with uncovered requirements for 1976. Most of the affected utilities went immediately into the market in an effort to obtain supplies to meet their requirements. Since some of the utilities required short-term deliveries of uranium, a sharp jump in prices occurred.

Two of Westinghouse's customers announced purchases of uranium in November 1975. Houston Lighting and Power purchased 1.25 million pounds of U_3O_8 for delivery in 1975–1977 at a price of about $28.60/lb., with ultimate price based on the market price at time of delivery. Duquesne Light Co. purchased 400,000 pounds for delivery in 1976–1978 at a price of $35/lb. plus escalation.

By mid-1976 the uranium market began to stabilize. The higher prices for uranium brought announcements of new capacity additions from the industry. Also, delays in reactor construction continued, causing a reduction in new orders for supply. Spot prices ceased their climb and did not rise enough during the year to offset inflation. Spot prices were around $40/lb. at the beginning of the year and $41 to $42/lb. at the end of the year.

In April 1977 ERDA announced its intention to meet with its LFTC customers who had scheduled enrichment services in excess of their actual requirements. The purpose of the meetings was to reschedule contractual requirements to be more in line with customers' needs. This event, in connection with the realization that many countries' ambitious nuclear construction programs were unrealistic, and the renewed optimism concerning the development of the vast Australian reserves, had a stabilizing effect on the market. However, several unfavorable events had the opposite effect, causing some continued upward pressure on prices in the spot market. These included: (1) new emphasis on safeguards by the Canadian Government, as a condition for its exports, which caused delays in delivery of material to Europe and Japan; (2) technical problems at the Rossing deposit in Southwest Africa, resulting in major delays in production; and (3) financial difficulties at the Mary Kathleen mine in Australia, resulting in lower than anticipated production.

During the mid-1977 to mid-1978 period, spot prices remained stable. Worldwide demand for uranium continued to decrease and non-U.S. buyers became more active in the U.S. market than domestic buyers due to the weakness of the U.S. dollar. Also, non-U.S. buyers became more inclined toward diversity of supply and thus increased their interest in U.S. supply. U.S. producers seemed more interested in small spot-market transactions than in long-term commitments and the newly announced DOE policy to convert LTFC contract to Adjustable Fixed Commitment (AFC) Contracts had a stabilizing effect on the market. Table 1 shows a list of representative U_3O_8 contracts and prices for the period 1966 through mid-1978.

TABLE I.—REPRESENTATIVE HISTORICAL U_3O_8 CONTRACTS (1966–78)

Seller	Buyer	Quantity (pounds U_3O_8)	Delivery years	Approximate date announced	Price—Comments
1966: United Nuclear	Commonwealth Edison	3,000,000	1970–72	July 1966	The total value of the contract was announced as $17,000,000. Based on this contract value, the price equates to $5.67/lb.
1967:					
United Nuclear	Commonwealth Edison	6,000,000	1968–74	January 1967	The total value of the contract was announced as $37,000,000. This contract value equates to a price of $6.17/lb.
Federal American	Babcock & Wilcox	750,000	1967–70	April 1967	The total value of the contract was announced as $4,500,000. This contract value equates to a price of $6/lb.
Western Nuclear	Combustion	3,500,000	1971–73	November 1967	The total value of the contract was announced as $26,000,000. Based on this contract value the price equates to $7.43/lb.
1968: Federal-American	Combustion	1,250,000	1970–71	July 1968	The contract was announced as having a total value of $17,000,000. This equates to a price of $6.17/lb.
1969:					
Atlas	Boston Edison	700,000	1969–70	April 1969	The base price was reported to be $6.30/lb. Escalation no more than $0.10/lb.
United Nuclear	Power Authority of the State of New York.	1,144,000	1971	August 1969	The base price was reported to be $6.95/lb. on a total contract value of $7,951,000.
1970:					
Mary Kathleen	Commonwealth Edison	4,250,000	1974–78	August 1970	Commonwealth was announced as the first U.S. buyer of foreign uranium. Based on the Australian producer's announcement of the total value of the contract, the average price was estimated to be $7.20/lb.
Continental Oil	TVA	2,913,000	1975–80	August 1970	Based on the contract's announced value of $22,863,750, the price equates to $7.85/lb.
Exxon	TVA	1,200,000	1976–79	September 1970	The total value of the contract was announced as $7,680,000. Based on this value, the price equates to $6.40/lb.
1971: Uranex	Kansai Electric	12,600,000	1974–86	June 1971	The base price was reported to be $6.25/lb for deliveries starting in 1974 with fixed increases through 1978 ranging up to about $7/lb. After that the price was to be negotiated year by year.
1972:					
Gulf Oil	Ranchers	5,000,000	1976–81	May 1972	The contract calls for delivery of between 5,000,000 to 10,000,000 lb. U_3O_8. The gross value of the contract for 5,000,000 lb. was announced as being $40,000,000, which equates to a price of $8/lb.
Uranium Canada	Spanish Utilities	9,000,000	1972–77	November 1972	The total value of the contract was announced as $60,000,000. This equates to a price of $6.50/lb.
1973:					
Reserve-Sohio	Gulf-General Atomic	5,750,000	1977–81	March 1973	The total value of the contract was announced as $50,000,000. This contract value equates to a price of $8.70/lb.
Uranex	Carolina Power & Light	8,150,000	1977–85	May 1973	The total value of the contract was announced to be in excess of $60,000,000. Based on a $60,000,000 total value, the price equates to $7.36/lb.
Kerr-McGee	CAPCO	12,800,000	1977–85	November 1973	The total value of the contract was reported to be $150,000,000. Sources estimated the price to be about $11.75/lb if per-pound costs of conversion are figured in.

TABLE I. REPRESENTATIVE HISTORICAL U_3O_8 CONTRACTS (1966–78)—Continued

Seller	Buyer	Quantity (pounds U_3O_8)	Delivery years	Approximate date announced	Price—Comments
1974:					
Gulf-General Atomic	Pennsylvania Power & Light	3,200,000	1980–85	February 1974	2 contracts for equal amounts of material were announced having a combined value of $100,000,000. Each contract was with a different supplier. Based on half of the value of the contract being associated with Gulf-General Atomic, the price equates to about $15.60/lb.
Rio Algom—Canada	BNFL	20,000,000	1982–92	June 1974	The base price for 1982 delivery was reported to be $16.90. Prices were reported to escalate to about $21/lb. for deliveries after 1986.
Kerr-McGee	Detroit Edison	3,000,000	1979–83	July 1974	Industry sources estimated the price to be in the range of $15–$16/lb. (An average price of $15.50/lb. was assumed for the contract.)
United Nuclear	Unidentified European	3,000,000	1976–78	July 1974	The total value of the contract was reported to be $40,500,000. This equates to a price of about $13.50/lb.
Rio Algom—Canada	TVA	17,000,000	1979–90	September 1974	The total base price of the contract was reported to be aboout $222,000,000. This value equates to a price of about $13.00/lb. The actual prices will be guided by world market prices at time of delivery.
Duke Power	Westinghouse	2,000,000	1974–75	October 1974	Industry sources estimated the price to be between $13.50 to $13.70/lb. (An average price of $13.60/lb. was assumed for the contract.)
1975:					
United Nuclear	Unidentified European	1,000,000	1977–78	January 1975	The total value of the contract was reported to be $15,000,000. Based on this value, the price equates to $15/lb. A prepayment of the total price was made into an escrow account at the time of contract signing to be released to United Nuclear as deliveries are made.
Reserve Oil	General Electric	300,000	1976–79	February 1975	The total value of the contract was announced as $5,700,000. This equates to a priceof $19/lb. A down payment of $2,100,000 was made to Reserve when the contract was signed.
Dawn Mining	West German interests	400,000	1975	March 1975	A base price of $16/lb was the only pricing information reported.
Rio Algom—Canada	Washington Public Power	1,000,000	1975	April 1975	The total value of the contract was reported to be $25,500,000 which includes conversion. A price of $22/lb U_3O_8 was reported.
Dawn Mining	Florida Power & Light	400,000	1975	May 1975	A base price of $20/lb was the only pricing information reported.
Western Nuclear	Washington Public Power	5,500,000	1979–83	July 1975	The total value of the contract was announced as $121,000,000, which equates to a price of $22/lb. Escalation was at a rate of 7 percent per year.
United Nuclear	Omaha Public Power	100,000	1976	October 1975	The total value of the contract was $26,700,000. A base price of $26.70/lb. was reported.
Solution Engineering	Omaha Public Power	382,000	1975	October 1975	The total value of the contract was reported to be $10,000,000. This equates to a price of about $26.20/lb.
Homestake	Omaha Public Power	1,600,000	1975; 1978–87	October 1975	Based on the projected total value of the contract, the price equates to about $23.30/lb. Actual prices will be determined by market prices at time of delivery.

Reserve Oil	Duquesne Light Co	400,000	1976–78	November 1975	The total value of the contract was announced as \$14,000,000. This equates to a price of about \$35/lb. Escalation adjustments to be vased on inflation. The price can be revalued periodically if market price exceeds the escalated base price.
Atlas	Houston Lighting & Power	1,250,000	1975–77	November 1975	The contract was announced as having a total value of about \$35,000,000. The price ultimately to be based on market price at time of delivery. Included in the contract are a minimum fixed price and substantial prepayments.
New Mexico & Arizona Land Co.	Yankee Group	800,000	1978–82	November 1975	The total value of the contract was announced as \$22,900,000. This value equates to a price of \$28.60/lb.
1976:					
American Nuclear	Florida Power & Light	1,000,000	1981–82	May 1976	Pricing terms based on market price at time of delivery. The base contract price will be \$38/lb but will vary with market price. The contract has a floor price of \$28/lb and a ceiling price of \$58/lb. An advance payment of \$3,000,000 30 days after contract signing and an additional \$3,000,000 over the following 3 yr.
Dawn Mining	Omaha Public Power	1,100,000	1976–80	July 1976	A base price of \$40/lb was included and adjusted upward or downward within specified limits based on spot market prices for 700,000 lb with 25 percent of market price paid every 6 mo in 1977–78. Moneys paid in advance for the 1st 400,000 lb.
Intercontinental Energy	Pacific Gas & Electric	1,300,000	1978–82	December 1976	The contract includes an advance payment of \$12,000,000. The price for the 1st 843,750 lb U_3O_8 set at \$40/lb. Further deliveries based on market price at time of delivery with a \$40/lb floor and a \$50/lb ceiling.
Homestake	Omaha Public Power	220,000	1977	December 1976	Price reported to be \$42/lb for 1977 delivery.
1977:					
Homestake	Sacramento Municipal Utility District.	600,000	1977–80	January 1977	Base price was reported to be \$40/lb with standard escalation
Omaha Public Power	Indiana & Michigan	200,000	1977	February 1977	Omaha sold material to Indiana & Michigan for \$41 50/lb. with the stipulation that Indiana & Michigan resell the material to Omaha at the same price.
Unidentified Japanese utility.	Anaconda	800,000	1977	May 1977	Price was reported to be at least \$43/lb.
1978:					
General Electric	Sacramento Municipal Utility District.	500,000	1978	March 1978	The material was purchased—as UF_6. The equivalent price was reported be \$43.05/lb. U_3O_8. Actual price was \$116.88 per KgU as UF_6.
United Nuclear	Unidentified non-U.S utility	1,060,000	1978	March 1978	Average price reported to be \$44.35/lb.
Cenex, Ltd	Public Service Electric & Gas, New Jersey.	240,000	1979	March 1978	The base price was reported to be \$41 75/lb. in January 1978 dollars with a flat escalation rate of \$0.20/mo.
United Nuclear	Taiwan Power Co	2,500,000	1978–82	June 1978	The base price was reported to be at least \$43/lb. plus escalation from March or April 1979.

Source: The History and Trends of U_3O_8 Prices, prepared for the Congressional Research Service by Nuclear Research Service Corp , December 1978

HISTORICAL INFORMATION ON URANIUM ENRICHMENT

A. The enrichment process

The process of increasing the concentration of U_{235} from 0.711 percent by weight, which exists in natural uranium, to the 3 to 4 percent required for fuel used in nuclear reactors is known as uranium enrichment. The industrial effort to enrich uranium is measured in terms of "separative work units" (SWU's). A SWU is the amount of work involved in increasing the concentration of U_{235} from its natural level to an amount necessary to sustain a nuclear chain reaction providing heat to produce electricity in a nuclear reactor. In order to enrich uranium to 3 to 4 percent U_{235}, this isotope must be "separated" from the U_{238} uranium isotopes and collected in greater concentration than exists in natural form. This separation can be described in terms of the quantities of material fed into and withdrawn from the enrichment process and the isotopic assay of each of these flow streams. This information can be combined into a single number which quatifies the process by a method of weighing the importance of each quantity and assay involved. The result is a measure of the separation effort involved and is described in terms of "units of separative work." [2]

After uranium is mined, the ore is sent through a milling process where it is converted into a uranium concentrate called yellowcake (U_3O_8).[3] This yellowcake contains U_{235} in its natural concentration of 0.711 percent by weight. The yellowcake is then converted into a gas called uranium hexafloride (UF_6). It is this gas which is the input to the enrichment process. During enrichment, two outputs are produced: enriched uranium containing 3 to 4 percent U_{235}, and the "tails," which is depleted uranium containing only 0.2 to 0.4 percent U_{235}. The enriched uranium is sent to a fabrication plant where it is formed into pellets and placed into zirconium tubes which are assembled into bundles for use in nuclear power plants. The depleted uranium is stored as a possible feed material for breeder reactors if these are ever used commercially.

Enrichment services are performed in the U.S. at three Government-owned plants located in Oak Ridge, Tennessee; Paducah, Kentucky; and Portsmouth, Ohio. These plants were built during and after World War II to produce highly enriched uranium for military purposes. They are currently used almost exclusively to supply enriched uranium for commercial purposes, except for highly enriched uranium to fuel the U.S. nuclear navy.

The three Government-owned enrichment plants use the gaseous diffusion method of enriching natural uranium. In this process, uranium hexafloride is diffused through a barrier. A slightly higher concentration of the lighter U_{235} atoms diffuse through the barrier than do the heavier U_{238} atoms, thus producing a slightly enriched mixture on the other side of the barrier. Since a single stage of the diffusion process only increases the concentration of U_{235} by factor of 1.00429, it takes a large number of stages to enrich natural uranium to 3 to 4 percent U_{235}. The diffusion process uses electrical energy for the pumps and to maintain the temperature and pressure of the feed stocks. Thus, large quantities of electric power are necessary to maintain the diffusion process. The DOE is currently involved in two programs designed to increase the capacity of the existing gaseous diffusion plants. The Cascade Improvement Program uses improved compressors and barriers to increase the amount of separation that a single stage can accomplish. The Cascade Uprating Program is designed to increase the flow of UF_6 through the cascade by increasing the electical power and improving the system. When completed in 1981, these programs will increase the capacity of the three Government-owned plants by 60 percent.

In operating the existing diffusion plants, the number of SWU's needed to produce a given amount of enriched uranium, depends upon the tails assay chosen. If the tails assay is high, say 0.4 percent U_{235} by weight, then more uranium will be needed to produce the desired output, but with less separative work required. Alternatively, a lower tails assay will require less feed stock but more separative work. Optimum economics of plant operation depend upon a complex balancing of the costs of uranium and of electricity. Accordingly, the capacity of a given plant in terms of tonnage of enriched uranium is not fixed. Output depends on the tails

[2] United States Atomic Energy Commission, AEC Gaseous Diffusion Plant Operations, Washington, D.C. U.S. Government Printing Office, ORO-684, 1972, p. 29. Reprinted in: The History of Enrichment Prices, Prepared for the Congressional Research Service by Nuclear Assurance Corporation, December, 1977, p. iii.

[3] Information contained in the reminder of this subsection was derived largely from: Uranium Enrichment and Public Policy, by Thomas Gale Moore, American Enterprise Institute for Public Policy Research, Washington, D.C. 1978.

assay, which in turn depends on the price of raw uranium and the cost of enrichment.

A second method of enriching uranium now being developed is the gas centrifuge process. The next scheduled addition to the Government's enrichment capacity is an 8.8 million SWU gas centrifuge plant at Portsmouth, Ohio. The centrifuge process operates by whirling uranium hexafloride in cylinders at high speed so that the centrifugal force pushes the heavier U_{238} atoms to the outside of the cylinder, leaving a greater concentration of the lighter U_{235} atoms on the inside where they can be extracted.

The gas centrifuge plant has several advantages over the gaseous diffusion plant. The capital requirements of the gas centrifuge plant are the same as for a gaseous diffusion plant of the same size; however, economies of scale are reached at the 3 million SWU's per year size, whereas the least efficient size of a gaseous diffusion plant is 3 times as large. Thus for plant expansion needs, smaller increments of additional capacity can be added to the centrifuge plant than to the gaseous diffusion plant. Also, the electricity required for a centrifuge plant is only 10 percent or less than that for a diffusion plant.

B. U.S. Government enrichment contracts

The Requirements Contract was originally offered by the AEC and was available until December, 1972. This type of contract stipulated that enrichment services will be supplied based upon the actual requirements of an individual reactor. With this type of contract, customers are not required to firm-up their enrichment service schedule until 180 days prior to delivery. Customers are required, however, to provide the Government with estimates of enrichment service requirements for a 5-year period. Requirements Contracts still in force now account for about one-third of the total enrichment currently under DOE contract. However, over the next several years, enrichment services provided under these contracts will represent about one-half to two-thirds of the total amount of enrichment services provided.[4] Table 2 lists the DOE enrichment services contracts with domestic and foreign customers by contract type, as of September 15, 1978.

The second type of contract used by the Government was the Long-Term Fixed Commitment Contract (LTFC). From September 1973 until July 1974, at which time the U.S. Government stopped accepting new enrichment service contracts, this contract was used for enrichment services. Under a LTFC contract, a customer must provide a firm schedule for enrichment services over a 10-year delivery period. The 10-year period is a rolling schedule, in that as each year's enrichment services are used, another year's requirements are added, thus maintaining a 10-year forward commitment.

TABLE 2.—DOE URANIUM ENRICHMENT SERVICES CONTRACTS AS OF SEPT. 15, 1978

Contract type	Gigawatts			Number of reactors		
	United States	Non-United States	Total	United States	Non-United States	Total
Requirements-type	75	25	100	87	47	134
Fixed-commitment:						
Firm	127	84	211	122	94	216
Conditional		1	1		1	1
Adjustable fixed-commitment						
Total	202	110	312	209	142	351

Source: U.S. Department of Energy.

In 1978, the DOE announced that domestic and non-U.S. contract holders would be given an opportunity to convert their present form of contracts to a new, more flexible type of contract called the Adjustable Fixed Commitment (AFC) Contract. This type of contract features a 5-year rolling firm commitment period, rather than the 10-year period required under the LTFC contract. Certain quantity and time adjustments also are permitted during the 5-year commitment period

[4] Uranium Enrichment Plans, a paper presented by David C. Thomas and Roger W. Gagne, Division of Uranium Resources and Enrichment, Department of Energy, Washington, D.C., October, 1978.

of the AFC contract. DOE enrichment customers were notified of a one-time opportunity to convert their LTFC contracts to AFC contracts in addition to adjusting firmly scheduled deliveries for a reduced schedule adjustment change. Customers were to notify DOE of their intention to convert by July 1, 1978. Almost all of the current LTFC contract holders gave notice of their intent to convert to the AFC contract. Table 3 lists the number of domestic and non-U.S. LTFC contract holders and the number of customers who took advantage of the conversion opportunity.

C. A price history of U.S. Government enrichment service

The DOE prices for separative work are determined by a 10-year forward cost estimate based on full cost recovery to the Government. This cost is below that which a commercial enterprise would charge since it does not include taxes or profit. Attempts have been made by the DOE to alter the bases of its pricing mechanism in order to have its prices more closely conform to those which would be charged by a privately-owned, commercial enterprise. These proposals, however, have not been approved by Congress.

Historical prices of DOE Requirements and LTFC contracts are listed in Table 4. The Requirements Contract price is limited by a ceiling price which is also shown in the table. If the announced DOE price exceeds the ceiling price, the ceiling price prevails. This price is determined by the following formula:

TABLE 3.—RESPONSES TO JULY 1, 1978, AFC OPTION

	Domestic	Non-United States	Total
Number of contracts	129	[1] 95	224
Number of responses	121	93	214
Responses indicating no conversion	0	3	3
Contracts desiring slippage	74	53	127
Average slippage in months	32	37	34

[1] Includes one conditional contract.

Source: U.S. Department of Energy.

TABLE 4.—U.S. DOE SEPARATIVE WORK PRICE HISTORY, DECEMBER 1978

[Dollar per SWU]

Period beginning	Fixed-commitment	Requirements-type [1]	Ceiling charge
May 1968		$26.00	$30.83
February 1969		28.70	34.02
November 1971		32.00	36.72
August 1973	$36.00	38.50	40.59
January 1974	36.40	38.90	40.83
July 1974	36.80	39.30	47.26
December 1974	42.10	47.80	
July 1975	42.85	48.80	59.80
August 1975	53.35		
December 1975		60.95	
April 1976	59.05		65.06
August 1976		67.25	65.83
October 1976	61.30		
January 1977		69.80	69.75
July 1977			67.58
November 1977	74.85		
January 1978			78.20
March 1978		83.15	
July 1978			86.38
December 1978	88.65		
January 1979			[2] 88.90
April 1979		98.30	
July 1979			[2] 92.74

[1] If announced requirements-type price is higher than the ceiling charge, then the ceiling price is the actual price charged.
[2] This is a DOE estimate, subject to revision.

Source: The History of Enrichment Prices, prepared for the Congressional Research Service by Nuclear Assurance Corp., December 1978. Data derived from DOE announcements published in the Federal Register.

DOE pricing formula:

$$\text{Ceiling price} = \$15.00 \ \frac{x}{(3.958)} + \$5.00 \ \frac{y}{(\$2.87)} + \$10.00$$

Where: \$15.00 is the base power cost portion
x is the current power cost in mills/kwh
3.958 is the base cost in mills/kwh (1965)
\$5.00 is the base labor portion
y is the current labor cost in 1 hour
\$2.87 is the base labor cost in \$/hour (1965)
\$10.00 is the fixed cost.

The pricing formula bears little relationship to the actual costs of operation of the enrichment facilities. It was created at a time when most enrichment facility information was classified in order to give some assurance of price stability to enrichment customers. From June 30, 1965 through December 1974, actual announced Requirements Contract prices were below ceiling prices. Since that time, announced Requirements Contract prices have tended to be close to, or above, the ceiling prices, due mainly to the rapid increase in electric power costs. Since these prices are expected to continue to increase in the future, and since both actual and ceiling prices are strongly affected by power costs, the prices of enrichment service is also expected to increase. Table 5 shows the components of the U.S. enrichment price for the period March through December 1978.

TABLE 5.—*Components of U.S. enrichment price for the period March 1978 to December 1978*

Component	*Charge (\$/SWU)*
Power	34.94
Other diffusion operating	5.65
Diffusion capital projects	6.18
Centrifuge development	3.80
Base plant and working capital	3.25
Split tails feed	1.80
Interest on preproduction (SW)	6.51
Advanced isotope separation	2.05
New plant costs	2.67
	66.85
Contingency at 15 percent	10.03
	76.88
Rounded to	76.90
Requirements-type contracts:	
Risk-charge	6.25
Requirements-type charge	83.15
Fixed-commitment contracts:	
Advanced payment credit	(2.05)
Fixed-commitment charge	74.85

Source: The History of Enrichment Prices, Prepared for the Congressional Research Service by Nuclear Assurance Corporation, December 1978. Data source: U.S. Department of Energy.

D. Non-U.S. suppliers of enrichment service

1. Uranium enrichment company

During the late 1950s, the United Kingdom, the Netherlands, and West Germany began working independently on centrifuge technology for uranium enrichment. At the request of the U.S. Government, this work was classified and the three countries continued to work individually through the 1960s. Subsequently, the three governments decided that international cooperation would be necessary to develop a fully competitive enrichment facility in Europe. On March 4, 1970, a treaty of collaboration among the three countries was agreed upon at Almelo, Netherlands. This treaty provided for the formation of two companies:

the prime contractor, to be sited in Germany and the enrichment organization located in the United Kingdom. Following ratification of the treaty, the two companies were formed; Gesellschaft fur Centirfugentechnik mbH (GENTEC) as the prime contractor and uranium Enrichment Company (URENCO) as the enrichment organization. Since all three countries had previously commissioned pilot plants, these plants were to continue to be built individually and turned over to URENCO upon completion. The combined design capacity of the plants is over 60,000 SWU/year.

At the end of 1973, a decision was made to construct two 200,000 SWU/year production plants to be located at Almelo, Netherlands and Capenhurst, Great Britain. Commissioning of the first plant began in late 1976 and construction of both facilities is continuing through late 1978. These plants are currently operating at a combined capacity of 300,000 SWU/year.

In late 1976, the Dutch industrial partners, which collectively own 15 percent of URENCO/CENTEC, announced their intention to withdraw their participation in any future plant expansions. Their decision to withdraw from participation was based on a reluctance to remain in partnership with the government and skepticism over the long-run profit outlook. A major reason for this skepticism was Urenco's serious shortage of delivery commitments through the 1980s. This situation was aggravated by the fact that a large percentage of contracts allow committed SWU deliveries to slip as reactor construction is delayed. Many of the reactors covered by these contracts have been delayed significantly. The withdrawal from participation of the Dutch companies might have affected expansion if the Dutch Government hadn't agreed in early 1978 to continue participation and to provide all of the Dutch share of the necessary financing.

The URENCO price for separative work is a base price subject to escalation provisions. The base price is specified in German marks but is subject to adjustment based on the exchange rate between the German mark, Dutch guilder and British pound. The escalation adjustment has been changed several times but is believed to consist of two formulas: one that applies from the date of contract execution until either four years prior to initial delivery when construction of URENCO's plant begins, or until initial delivery after construction of the plant is completed; and a separate formula which applies thereafter. The first formula has 100 percent escalation and includes a construction cost index. The second formula has a lower percentage of base cost subject to escalation which includes only materials, personnel and electricity costs. Both formulas escalate one-third of the portion of the price subject to escalation with indices for each country participating in URENCO.

2. Eurodif

The French Commissariat a l'Energie Atomique (CEA) has been developing the gasious diffusion process of isotope separation since 1953. The Pierrelatte complex was constructed in the early 1960s and began production in 1964. The facility reached its rated capacity of 400,000 SWU/year in April 1967. The complex is government owned and only a portion of the capacity is available for commercial reactor fuel.

In March 1972, Eurodif was formed as a joint venture to study the feasibility of constructing a 9 million SWU/year diffusion plant. In November 1973, the partners from France, Belgium, Spain and Italy, with government backing, decided to proceed with the plant. This decision was reached at a time when all of the partner countries were establishing major nuclear programs largely as a result of the Arab oil embargo.

The estimated production of the facility through 1990 was quickly sold out and in January 1975 a decision was made to expand the annual capacity of the facility from 9 million to 10.8 million SWU/year. Eurodif partners are committed to take 90 percent of production through 1990, with the remaining 10 percent committed to organizations in West Germany, Switzerland and Japan.

In July 1975, a new partner, the Atomic Energy Organization of Iran (AEOI) was added to the project. AEOI's participation is held through the Franco-Iranian company Sofidif. Construction of the Eurodif plant is estimated to take seven years, from 1974 to late 1981 with startup operation scheduled for December 1978. The estimated cost of the plant i 10 7 billion French francs.

The price of output of the Eurodif plant is a base price, which was 350 French francs in January 1974, subject to escalation and certain taxes. The most recent known escalation formulas are:

(1) For year T in the period 1/1/70 to 1/1/85:

$$PT = P74\left(0.10 + 0.50\,\frac{\text{Manpower T}}{\text{Manpower 74}} + \frac{\text{Equipment and Consulting T}}{\text{Equipment and Consulting 74}}\right)$$

(2) For year T after 1/1/85:

$$PT = P85\left(0.40 + 0.30\,\frac{\text{Manpower T}}{\text{Manpower 74}} + 0.30\,\frac{\text{Operating Costs T}}{\text{Operating Costs 85}}\right)$$

Where: Manpower 74 is the cost of manpower in 1974
Manpower T is the cost of manpower in year T
Equipment and consulting 74 is the cost of equipment and consulting in 1974
Equipment and consulting T is the cost of equipment and consulting in year T
Operating Costs 85 are the cost of operation in 1985
Operating Costs T are the costs of operation in year T

Advance payments are required to be paid over a 5-year period beginning with contract execution and credit without interest is applied over several years. The amount of the advance payment depends on the years of delivery but averages about 3 percent for each of five years.

3. Techsnabexport

During the 1950's, the Soviet Union developed and built an enrichment plant using gaseous diffusion technology with a capacity of 7 million to 10 million SWU/year. The plant was built for military purposes but was later used to supply fuel for nuclear generation programs within the Soviet Union, various satellite countries, and to fuel reactors exported to Finland. Recognizing the potential to earn "hard currency" through the export market, the Soviet Union began exporting enrichment service to other countries in 1973 when a long-term agreement was reached with a West German utility. Since that time, additional contracts have been completed with organizations in West Germany, the United Kingdom, Austria, Italy, Spain, Sweden, and France. The sole agent for export is Vsesojuznoje Exportno-Importnoe Objedinenije (Techsnabexport).

Techsnabexport's contract price is tied to the DOE price for enrichment service. In most cases it is the same as DOE's price although several early contracts granted customers a 5 percent discount from the DOE price. Contract price is established six months in advance of the year of delivery. Known, non-U.S. enrichment prices for the period 1973 through 1978 are listed in Table 6.

TABLE 6.—NON U.S. ENRICHMENT PRICES, DECEMBER 1978

Year	URENCO (Deutsche mark)	U.S. dollar equivalent	EURODIF (French franc)	U.S. dollar equivalent	TECHSNAB-EXPORT
1973	120		235		$36
1974	140		350	$57	[1] 37
1975	240	$100		106	43
1976					59
1977		120		110	61
1978			600	135	75

[1] Some at $32.

Source: The History of Enrichment Prices, prepared for the Congressional Research by Nuclear Assurance Corp. December 1978, table 3, p. 7.

IV. THE EFFECT OF ELECTRIC POWER COSTS ON U.S. ENRICHMENT PRICE

In this section, a comparison is made between the cost of U.S. Government enrichment service for Fiscal Year 1976, as determined by the DOE using actual costs of electric power, and the cost of enrichment service computed under the assumption of using the cost of imported fuel oil in the generation of electric power for the enrichment process. At present, Government enrichment plants are provided electric power from three sources: the Tennessee Valley Authority (TVA) supplies power to both the Oak Ridge and the Paducah plants; Electrical Energy, Inc. (EEI) supplies power to Paducah; and the Ohio Valley Electric Corp. (OVEC) supplies power to the Portsmouth plant. All of these producers supply electric power to the enrichment facilities under long-term arrangements with DOE using 100 percent coalfired generation. By comparing the cost of coal used in generation of power supplied to the enrichment plants with the cost of imported fuel oil, the effect on the price of uranium enrichment of using imported fuel oil rather than domestic coal can be determined. This analysis is undertaken because domestic coal is one of the cheapest fuels used to generate electricity and imported fuel oil is one of the most expensive. It can be argued by some that using one of the cheapest sources of energy (coal) as an input to the production of another energy source (nuclear power) provides a form of subsidy to the end-product energy source, if the energy supplied from coal exceeds the energy dreived from enriched uranium. This situation might take on additional significance if one considers the fact that Government enrichment services are sold to foreign as well as domestic customers. In this case, the U.S. is exporting uranium which has been enriched through a process using an inexpensive domestic fuel source, while at the same time importing more costly fuel oil which is used to provide energy for domestic consumption.

Table 7 shows the cost of purchased power for the three U.S. Government uranium enrichment facilities for Fiscal Years (FY) 1975, 1976, and for FY 1976 including the transition quarter to September 30, 1976. This information was taken from the financial statements of the Government enrichment service program. The information which we are interested if for the current analysis is that for FY 1976.

TABLE 7.—ELECTRIC POWER COSTS OF THE URANIUM ENRICHMENT SERVICES ACTIVITY, FISCAL YEAR, 1975, 1976, AND TRANSITION QUARTER

	15 mo ended Sept. 30, 1976			Fiscal year ended June 30, 1976			Fiscal year ended June 30, 1975		
	Kilowatt hours	Cost (thousands)	Mills per kilowatt-hour	Kilowatt-hours	Cost (thousands)	Mills per kilowatt-hour	Kilowatt-hours	Cost (thousands)	Mills per kilowatt-hour
Oak Ridge, Tenn.:									
TVA purchased power	14, 369, 847	$199, 747	13. 90	11, 594, 537	$157, 806	13. 61	9, 447, 430	$91, 398	9. 67
Power reduction surcharge credit								(3, 171)	
TVA purchased power—net	14, 369, 847	199, 747	13. 90	11, 594, 537	157, 806	13. 61	9, 447, 430	88, 227	9. 34
Undistributed line losses and other power consumption	(356, 658)			(273, 425)			(225, 330)		
Distribution cost		3, 686			2, 814			1, 990	
Use tax		2, 425			1, 796			914	
Charges to other users	(1, 068, 796)	(16, 296)	15. 25	(839, 049)	(12, 491)	14. 89	(821, 095)	(8, 717)	10. 62
Net charges to cascade	12, 944, 393	189, 562	14. 64	10, 482, 063	149, 925	14. 30	8, 401, 005	82, 414	9. 81
Paducah, Ky.:									
TVA purchased power	11, 224, 235	157, 390	14. 02	8, 858, 435	121, 620	13. 73	8, 737, 747	83, 351	9. 54
Power reduction surcharge credit								(4, 641)	
TVA purchased power-net	11, 224, 235	157, 390	14. 02	8, 858, 435	121, 620	13. 73	8, 737, 747	78, 710	9. 01
EEI purchased power	8, 935, 575	123, 500	13. 82	7, 314, 220	98, 752	13. 50	4, 950, 129	61, 446	12. 41
Undistributed line losses and other power consumption	(229, 063)			(181, 473)			(155, 609)		
Distribution cost		2, 452			2, 003			1, 592	
Charges to other users	(224, 957)	(3, 165)	14. 07	(177, 678)	(2, 434)	13. 70	(158, 330)	(1, 635)	10. 33
Net charges to cascade	19, 705, 790	280, 177	14. 22	15, 813, 504	219, 941	13. 91	13, 373, 937	140, 113	10. 48
Portsmouth, Ohio:									
OVEC purchased power	17, 512, 190	160, 436	9. 16	13, 339, 781	116, 590	8. 74	9, 639, 564	89, 856	9. 32
Undistributed line losses and other power consumption	(447, 936)			(348, 271)			(251, 558)		
Distribution cost		3, 330			2, 710			2, 120	
Charges to other users	(176, 597)	(1, 702)	9. 64	(136, 497)	(1, 243)	9. 11	(99, 580)	(966)	9. 70
Net charges to cascade	16, 887, 657	162, 064	9. 60	12, 855, 013	118, 057	9. 18	9, 288, 426	91, 010	9. 80
Total charges to cascade	49, 537, 840	631, 803	12. 75	39, 150, 580	487, 923	12. 46	31, 063, 368	313, 537	10. 09

Source: "Uranium Enrichment Services Activity," financial statements for the period ending Sept. 30, 1976, Energy Research and Development Administration—ERDA 77–27, Washington, D.C., March 31 1977, Schedule D, p. 14.

The table shows that for FY 1976 the cost of electric power to the Oak Ridge facility was 13.61 mills per KWH (a mill is one-tenth of a cent). After accounting for undistributed line losses and other power consumption, distribution cost, use tax and charges to other users, the cost of power to Oak Ridge is 14.30 mills per KWH. Similarly, the cost of electric power to the Paducah facility is reported as 13.91 mills KWH, and for the Portsmouth plant it is 9.18 mills KWH. The weighted average cost of electric power for all three facilities is reported, for FY 1976, to be 12.46 mills/KWH.

Table 8 shows the cost of production and sales of Government enrichment service for FY 1975, 1976, and FY 1976 including the transition quarter. Again, we are interested in the FY 1976 figures. This table shows the electric power costs, which are taken from Table 7, and the other cost elements of separative work, to derive the cost of production both in total dollars and on a per SWU basis. Table 8 shows that for FY 1976 the cost of separative work was $42.59/SWU. After accounting for inventories, the cost of separative work sold is reported at $33.80/-SWU.

These figures show that inventories have a large effect on the cost of sales of Government enrichment service. This is because the Government has accumulated inventories of separative work (enriched uranium) from previous years when costs of production, particularly electric power costs, were much lower than at present. Because these inventories have accumulated over a number of years, at various cost ratios and prices for electric power, it is not possible to determine the electric power cost component of the inventory in order to reprice it to reflect imported fuel oil costs rather than domestic coal costs. Therefore, the current analysis will determine the effect of imported fuel oil costs on FY 1976 production of enriched uranium and compare this cost with that shown in Table 8. The effect of inventories on the cost of separative work sold will not be considered.

TABLE 8.—COST OF PRODUCTION AND SALES OF SEPARATIVE WORK FOR THE URANIUM ENRICHMENT SERVICES ACTIVITY FISCAL YEARS 1975, 1976, AND TRANSITION QUARTER

	15 mo. ended Sept. 30, 1976			Fiscal year ended June 30, 1976			Fiscal year ended June 30, 1975		
	Separative work units	Cost (thousands)	Per unit of separative work	Separative work units	Cost (thousands)	Per unit of separative work	Separative work units	Cost (thousands)	Per unit of separative work
Enrichment operations:									
Power cost (schedule D)		$631, 804	$35. 07		$487, 924	$34. 21		$313, 537	$26. 97
Direct and indirect labor		9, 624	. 53		7, 887	. 55		7, 051	. 61
Maintenance services		16, 321	. 91		12, 238	. 86		7, 870	. 68
Technical services		4, 419	. 25		3, 643	. 26		3, 714	. 32
Decontamination and uranium control		4, 612	. 26		3, 739	. 26		2, 779	. 24
Plant test program		6, 444	. 36		4, 477	. 31		3, 115	. 27
Lighting, water and other utilities		13, 073	. 73		10, 165	. 71		7, 755	. 67
Depreciation expense (note 7)		64, 385	3. 57		50, 346	3. 53		40, 546	3. 49
Operating supplies and expense		2, 259	. 12		1, 294	. 09		734	. 06
General plant services		15, 048	. 83		11, 356	. 80		8, 422	. 72
Other process services		2, 750	. 14		1, 917	. 14		1, 461	. 12
General and administrative		14, 043	. 78		11, 401	. 80		9, 227	. 79
Allowance for feed material loss (note 9)		1, 248	. 07		1, 002	. 07		876	. 07
Total	18, 014	784, 850	43. 62	14, 263	607, 389	42. 59	11, 627	407, 087	35. 01
Less—Feed produced from tails recycle (note 3)	1, 135	49, 525	43. 62	901	38, 349	42. 59			
Total	16, 879	736, 325	43. 62	13, 362	569. 010	42. 59	11, 627	407, 037	35. 01
Add—Beginning in process inventory	1, 927	65, 705	34. 10	1, 927	65, 705	34. 10	1, 500	40, 501	27. 01
Total	18, 806	802, 030	42. 65	15, 289	634, 745	41. 52	13, 127	447, 588	34. 10
Less—Ending in process inventory	2, 453	104, 598	42. 65	2, 224	92, 339	41. 52	1, 927	65, 705	34. 10
Cost of finished production	16, 353	697, 432	42. 65	13, 065	542, 406	41. 52	11, 200	381, 883	34. 10
Add—Beginning finished inventory	19, 471	557, 215	28. 62	19, 471	557, 215	28. 62	15, 251	375, 093	24. 59
Cost of separative work available for sale	35, 824	1, 254, 647	35. 02	32, 536	1, 099, 621	33. 80	26, 451	756, 976	28. 62
Less—Ending finished inventory	25, 675	899, 214	35. 02	24, 545	829, 565	33. 80	19, 471	557, 215	28. 62
Cost of separative work sold (exhibit II)	10, 149	355, 433	35. 02	7, 991	270, 056	33. 80	6, 980	199, 761	28. 62

Source: "Uranium Enrichment Services Activity," financial statements for the period ending Sept. 30, 1976, Energy Research and Development Administration—ERDA 77–27, Washington, D.C., Mar. 31, 1977, schedule C, p. 13.

In order to determine the effect of imported fuel oil cost on the cost of electric power provided to the Government enrichment process, it is first necessary to determine the cost of coal used in the generation of electric power for the three sources of supply to the Government. The National Coal Association publishes annually a report entitled "Steam Electric Plant Factors," from which the weighted cost of coal used in generating electricity for TVA, EEI and OVEC, for 1976, was determined. This publication shows the quantity of coal delivered during 1976 to each generating unit on a company's system (in tons), the average BTU per pound of coal delivered (British Thermal Unit, a measure of the heat content of the coal), the average cost of coal in dollars per ton, and the average cost of coal in dollars per million BTU.[5] From this data, the weighted cost of coal delivered during 1976 to each supplier of electric power to the Government enrichment facilities in dollars per million BTU was computed.

Next it is necessary to determine the cost of imported fuel oil. The weighted average import cost of No. 6 residual fuel oil (.031–1.0 percent sulfur content) was determined using wholesale import prices for 1976 as contained in Federal Energy Administration (FEA) Form p. 302 (subject to price rules as outlined under 10CFR–212.83B). This form lists import quantities and values by origin, with the exception of imports originating from Amerada-Hess's Virgin Island operations. (Amerada-Hess typically provides approximately 20 percent of total imports of this fuel; however, the company does not supply value of shipment information. The weighted average import price calculated for cost comparison purposes, then, does not include shipments from this source.)

From the FEA Form p. 302, representative unit values of imported residual fuel oil, on a per barrel basis, were determined by month for 1976. These monthly prices were aggregated (using quantity weights) to arrive at a weighted average wholesale import price for the year. Since utility companies typically pay the retail price for residual fuel oil, the weighted average wholesale price was adjusted by 8.7 percent (the weighted average wholesale-to-retail price spread for 1976). The final result is the price of imported residual fuel oil typically paid by U.S. utility companies during 1976. This price is in dollars per barrel, which was then converted to dollars per million BTU (MMBTU).

Following the determination of the 1976 price of coal used in generation and the price of imported residual fuel oil, it is necessary to determine what percentage fuel costs are of the total cost of generation for each supplier of electric power. This information was obtained for EEI and OVEC from data contained in the Department of Energy's (DOE) "Statistics of Privately Owned Electric Utilities in the United States," 1976, and for TVA from the "Annual Report of the Tennessee Valley Authority," 1976, Volume II—Appendices. The DOE report contains annual data for each company on total KWH sales, total revenue from sales, and total fuel expense. From these data are computed average revenues in mills per KWH and average fuel cost in mills per KWH. The TVA Annual Report contains data for each generating unit on total KWH generation, total production expense and total fuel cost. From these data are computed the weighted average total production expense in mills per KWH and weighted average fuel expense in mills per KWH. From these figures, then, the percentage of fuel cost to total revenue from sales is computed. This information is contained in Table 9. The figures for TVA are given separately for its generation facilities in Tennessee and in Kentucky. The data from its Annual Report are for FY 1976 rather than calendar 1976. This slight difference in time period should provide no major difficulty for our analysis.

Using the statistical information contained in Table 9 and the electric power cost information contained in Table 7, it is then possible to compute the cost of electric power to the Government enrichment facilities, assuming that imported

[5] Steam Electric Plant Factors, 1977, National Coal Association, Washington, D.C., Table 5, pp. 70–97.

residual fuel oil, rather than domestic coal, is used as fuel in the generation of electric power. By assuming that fuel cost represents the same proportion of total charges to the Government enrichment facilities as it does to average total revenue for EEI and OVEC, and average total production expense for TVA, and then adjusting this cost to represent the increase in cost of imported fuel oil over coal, the cost of electric power to the enrichment facilities, assuming fuel oil generation, can be computed. This process is displaed in Table 10. For example, Table 7 shows that the cost of purchased power to the Oak Ridge facility from TVA for 1976 was 13.61 mills/kWh. Assuming that fuel cost represents 78.8 percent of this cost (the same percentage of fuel expense to total production expense listed in Table 9), and adjusting this cost to represent the increase in cost of imported fuel oil over coal (220.7% increase in this example), the fuel cost component of purchased power then becomes 23.64 mills/kWh. Adding in the remaining cost of purchased power (these costs would not be affected by fuel cost) results in an "adjusted" cost of purchased power of 26.54 mills/kWh (as compared with the 13.61 mills/kWh actually charged). The cost of purchased power from the other sources of supply are adjusted in the same manor.

The information contained in Table 10 lets us recalculate the total cost of electric power to the Uranium Enrichment Services Activity under the assumption that imported residual fuel oil is used in the generation of electric power. This information is contained in Table 11 which is a reproduction of Table 7 1976 data using the recalculated purchased power cost figures. This table shows a total cost of electric power to the enrichment facilities of 23.58 mills/kwh, as compared with 12.46 mills/kwh shown in Table 7. Finally, the effect on the cost of production of separative work (for 1976 excluding inventory adjustments) is presented in Table 12. This table shows the cost of separative work to be $75.28 per SWU as compared with $42.59 per SWU as listed in Table 8.

TABLE 9.—STATISTICAL INFORMATION FOR EEI, OVEC AND TVA, AND COST OF IMPORTED RESIDUAL FUEL OIL, 1976

	Electric Energy, Inc. (EEI)	Ohio Valley Electric Corp. (OVEC)	Tennessee Valley Authority (TVA), Tennessee	Tennessee Valley Authority (TVA), Kentucky
Weighted average price per million Btu of coal [1]	$0.96	$0.64	$0.92	$0.66
Average price per million Btu imported residual fuel oil [2]	$2.03	$2.03	$2.03	$2.03
Total kilowatt-hour sales [3]	9,034,142,221	17,854,872,346		
Total kilowatt-hour Generation (less station use) [4]			47,018,568,000	20,666,779,000
Total revenue from sales of electricity [3]	$162,054,471	$168,792,926		
Weighted average total production expense [4] (mills per kilowatt-hour)			11.74	8.7
Total fuel expenses [3]	$65,930,250	$50,530,550		
Average total revenue from sales of electricity (mills per kilowatt-hour)	17.94	9.45		
Average fuel expense (mills per kilowatt-hour)	7.30	2.83	9.24	6.3
Fuel expense as a percentage of average total revenue	40.7	29.95		
Fuel expense as a percentage of total production expense			78.7	72.4

[1] Steam Electric Plant Factors, 1977, National Coal Association.
[2] FEA form P. 302.
[3] Statistics of Privately Owned Electric Utilities in the United States, 1976, U.S. Department of Energy.
[4] Annual Report of the Tennessee Valley Authority, 1976, vol. II—Appendices, Tennessee Valley Authority, Knoxville, Tenn.

TABLE 10.—ADJUSTED COST OF PURCHASED POWER TO GOVERNMENT ENRICHMENT FACILITIES, 1976

Oak Ridge, Tenn.:	
TVA purchased power cost (table 7) (mills per kilowatt-hour)	13.61
Fuel cost as a percent of production expenses (table 9)	78.7
TVA purchased power fuel cost (13.61×78.7 percent) (mills per kilowatt-hour)	10.71
Percent increase of imported residual fuel oil cost over TVA coal cost	220.7
TVA purchased power fuel cost assuming use of imported residual fuel oil (10.71×220.7 percent) (mills per kilowatt-hour)	23.64
Total adjusted cost of TVA purchased power:	
Mills per kilowatt-hour fuel cost	23.64
Mills per kilowatt-hour other production cost	2.90
Total, mills per killowatt-hour	26.54
Paducah, Ky.:	
TVA purchased power cost (table 7) (mills per kilowatt-hour)	13.71
Fuel cost as a percent of production expense (table 9)	72.4
TVA purchased power fuel cost (13.71×72.4 percent) (mills per kilowatt-hour)	9.94
Percent increase of imported residual fuel oil cost over TVA coal cost	309.5
TVA purchased power fuel cost assuming use of imported residual fuel oil (9.94×309.5 percent) (mills per kilowatt-hour)	30.76
Total adjusted cost of TVA purchased power:	
Mills per kilowatt-hour fuel cost	30.76
Mills per kilowatt-hour other production cost	3.79
Total, mills per kilowatt-hour	34.55
EEI purchased power cost (table 7) (mills per kilowatt-hour)	13.50
Fuel cost as a percent of total revenue (table 9)	40.7
EEI purchased power fuel cost (13.50×40.7 percent) (mills per kilowatt-hour)	5.49
Percent increase of imported residual fuel oil cost over EEI coal cost	211.2
EEI purchased power fuel cost assuming use of imported residual fuel oil (5.49×211.2 percent) (mills per kilowatt-hour)	11.59
Total adjusted cost of EEI purchased power:	
Mills per kilowatt-hour fuel cost	11.59
Mills per kilowatt-hour other production cost	8.01
Total, mills per kilowatt-hour	19.60
Portsmouth, Ohio:	
OVEC purchased power cost (table 7) (mills per kilowatt-hour)	8.74
Fuel cost as a percent of total revenue (table 9)	29.95
OVEC purchased power fuel cost (8.74×29.95 percent) (mills per kilowatt-hour)	2.62
Percent increase of imported residual fuel oil cost over OVEC coal cost	315.2
OVEC purchased power fuel cost assuming use of imported residual fuel oil (2.62×315.2 percent) (mills per kilowatt-hour)	8.26
Total adjusted cost of OVEC purchased power:	
Mills per kilowatt-hour fuel cost	8.26
Mills per kilowatt-hour other production cost	6.12
Total, mills per kilowatt-hour	14.38

TABLE 11.—ADJUSTED PURCHASED POWER COST TO URANIUM ENRICHMENT SERVICES ACTIVITY, 1976

Power costs, fiscal year 1976	Kilowatt-hour	Cost (thousands)	Mills/per kilowatt-hour
Oak Ridge, Tenn.:			
TVA purchased power cost	11,594,537	$307,719	26.54
Undistributed line losses and other power consumption	(273,425)		
Distribution cost		2,814	
Use tax		3,502	
Charges to other users	(839,049)	(24,357)	29.03
Net charges to cascade	10,482,063	284,050	27.10
Paducah Ky.:			
TVA purchased power	8,858,435	306,059	34.55
EEI purchased power	7,314,220	143,358	19.60
Undistributed line losses and other power consumption	(181,473)		
Distribution cost		2,003	
Charges to other users	(177,678)	(4,968)	27.96
Net charges to cascade	15,813,504	446,452	28.23
Portsmouth, Ohio:			
OVEC purchased power cost	13,339,781	191,826	14.38
Undistributed line losses and other power consumption	(348,271)		
Distribution cost		2,710	
Charges to other users	(136,497)	(2,046)	14.99
Net charges to cascade	12,855,013	192,490	14.97
Total charges to cascade	39,150,580	922,992	23.58

TABLE 12.—ADJUSTED COST OF PRODUCTION OF SEPARATIVE WORK FOR THE URANIUM ENCRICHMENT SERVICES ACTIVITY, 1976

Cost of production, fiscal year 1976	Separative work units (thousands)	Cost (thousands)	Per unit of separative work
Enrichment operations:			
Power cost (as revised)		$922,992	$64.71
Direct and indirect labor		7,887	.55
Maintenance services		12,238	.86
Technical services		3,643	.26
Decontamination and uranium control		3,739	.26
Plant test program		4,477	.31
Lighting, water, and other utilities		10,165	.71
Depreciation expense		50,346	3.53
Operating supplies and expenses		1,294	.09
General plant services		11,356	.80
Other process services		1,917	.14
General and administrative		11,401	.80
Allowance for feed material losses		1,002	.07
Total	14,263	1,042,457	73.09
Less—Feed produced from tails recycle	901	38,349	42.56
Total	13,362	1,013,175	75.83

IV. SUMMARY AND CONCLUSIONS

This report has provided historical information on prices of U.S. uranium production and on U.S. Government enrichment services. Because the U.S. Government has been a major purchaser of uranium worldwide, information on non-U.S. production has also been included in this report.

The uranium industry in the U.S. developed to supply uranium for the United States and United Kingdom weapons program. The AEC's purchase program encourged development of domestic uranium production through guaranteed prices and limitations on imports. With the development of the commercial nuclear reactor industry, the AEC ended its purchase program in 1958 thereby contributing to a reduction in exploration and development of new uranium reserves and an over-capacity situation for the industry. Other factors such as delays in construction and cancellations of nuclear reactors also contributed to the over-capacity situation.

Since the Government is the only domestic supplier of enrichment services, its policies in this area continue to affect the uranium production and nuclear reactor industries. The Long-Term Fixed Commitment Contract, initiated by the AEC in 1973, contributed to a temporary short-supply situation due to the long-term fixed commitment of feed uranium and separative work required by this type of contract. In 1978, the Department of Energy allowed its enrichment customers to convert their LTFC contracts to a new, more flexible type of contract called the Adjustable Fixed Commitment Contract, thereby helping to alleviate the supply shortage. Other factors contributing to the supply shortage, and resulting rising prices, included the Arab-oil embargo, Westinghouse Electric Corporation's inability to supply uranium to its customers, and delays in production from foreign uranium producers.

Price for Government supplied enrichment service have continued to increase, largely due to the increasing cost of electricity, a major factor input to the enrichment process. Several non-U.S. suppliers of enrichment service have entered the market, all with government involvement. Various prices are charged for enrichment service by these suppliers, subject to escalation provisions. One of these suppliers, the Soviet Union, ties its price to that charged by the U.S. Department of Energy.

Finally, this report shows the effect on the cost of production of enriched uranium of substituting imported fues oil for domestic coal in the generation of electric power supplied to enrichment facilities. This analysis shows a substantial impact on the cost of production of enriched uranium due to the increased cost of electricity.

O